Geological Society of America Special Papers

Mining and Metallurgy in Ancient Perú

Georg Petersen G. and William E. Brooks

Geological Society of America Special Papers 2010;467;xvii-90
doi: 10.1130/2010.2467

Mining and Metallurgy in Ancient Perú

by
Georg Petersen G.

translated by
William E. Brooks

*Los dos Españoles la llaman Laguna de Chuchiabo, topónimo Aymara,
muy sugestivo y de gran colorido en el monótono y melancólico
paisaje del Altiplano cuyos límites se esfuman en el aire diáfano
de las serranias agrestes circundantes y donde en el transcurso de
los remotos tiempos geológicos las "lágrimas del Sol" se vertieron
copiosamente para cristilarze en los opulentos yacimientos auríferos…*

*Crónica de la Conquista del Perú
Anónimo de Sevilla, 1534*

Prologue

The pre-Columbian miner explored widely in ancient Perú and exploited its mineral resources using simple tools of bone or horn for rudimentary open-pit and underground workings. Numerous rocks, minerals, and metals, either obtained from smelting or as native metals, played an important role in development of the Andean and coastal Peruvian cultures. Such use can be dated at archaeological sites where the first inhabitants of South America are thought to have appeared more that 19,000 years ago.[1]

During the first millennium B.C., a second stage took place with the fabrication of metallic objects by the Chavin. These objects were mainly of gold, silver, copper, and bronze with minor use of platinum, tin, lead, and mercury. Peruvian metallurgy dates to the time of the Chavin (700–500 B.C.) and continued even upon the arrival of the Spaniards.

Mining during ancient times was mystical and religious. The ancient Andeans felt intimately connected with nature and the mines that provided the metals were worshipped and given offerings. Padre Calancha (1638) described how the ancient Peruvians worshipped their gold mines (*chuqui*), their silver mines (*coya*), and mines that yielded other metals (*corpa*). Pyrite, cinnabar (*llimpi*), and the furnaces (*huayras*) used for smelting were also revered.

Padre Bernabé Cobo (1652, Libro XIII, c. XI, p. 166) observed that those who worked the mines also worshipped the hills and the mines, which were called *coya*, and were asked to yield their mineral wealth. The miners danced, drank, and left candles in order to glorify their prayers. They worshipped the metals that were called *mama* and the shiny pyrite called *corpa*. Sulfur, *soroche*, silver, the smelting ovens, and the gold nuggets and flakes were revered and blessed. Cinnabar was called *llimpi* and according to Morúa (1925), was a very mystical metal.[2] This regard for the wealth of the mineral world was such that rare stones were regarded as idols and were not used for offerings. The themes of mining and metallurgy in ancient Perú were aesthetic, utilitarian, and religious.

There has been much speculation on the absence of iron artifacts in Peruvian archaeology, especially given the fact that iron minerals are present in Perú. The absence of metallic iron in the archaeological record is significant and it is important to say that when the Spanish Conquest took place, the ancient Peruvians had not evolved beyond copper-bronze technology. Even though they had perfected other types of metal technology, ironwork demanded an advanced process that the ancient Peruvians had not achieved. The ancient Peruvians, as well as other Native American groups, had not reached the Iron Age, but were in transition when they were brutally confronted by a foreign nation that readily applied its knowledge of iron metallurgy to tools and weapons.

Acknowledgments

For cooperation and collaboration, sample analysis, and other support, I wish to express my appreciation and gratitude to the following institutions, scientists, and individuals:

Universidad Nacional de Ingeniería, Departamento de Geología; Servicio Nacional de Geología y Minería del Ministerio de Energía y Minas; Compañía de Minas Buenaventura S.A.; Cerro de Pasco Corporation; Mauricio Hochschild y Cía. Ltda. (Mina Raúl); Compañía Miñera Pativilca, S.A.; Museo Nacional de Antropología y Arqueología; Museo Arqueológico Rafael Larco Herrera; Museo Arqueológico Amano; Museo Oro del Perú; Ing. Guillermo Abele; Arqto. Santiago Agurto Calvo; Ing. Mario Arenas; Sr. Paulino Arias; Ing. Juan Ayza; Ing. Alfonso Barreda M., Ing. José Becerra (Casa de Moneda, Lima); Dr. Junius Bird; Dr. Duccio Bonavia; Prof. Fernando Corantes; Ing. Julio Dávila V.; Dr. Estanislao Dunin-Borkowski; Dr. E.R. Caley; Sra. A. Cucchi; Dr. César Cánepa; Dr. H.D. Disselhoff; Sr. O. Fernández de Cordova Amézaga; Ing. J. Fernández Concha; Dr. Ramón Ferreyra; Srta. Angela Florez; Ing. Mariano Iberico; Ing. Franz Langer; Srta. Heather Lechtman; Sra. Marta Macedo de Rojas; Ing. Luis De Montreuil; Dr. Jorge Muelle; Ing. José Peña Prado; Ing. C. Richard Petersen; Dr. Ulrich Petersen; Sr. Rogger Ravines; Dra. Rosalvina Rivera C.; Ing. César Sotillo Palomino; Dr. Hermann Trimborn; Sir John Wilson, Ph.D.

Special thanks to Dr. Duccio Bonavia, Dr. César Cánepa, and Dra. Rosalvina Rivera who graciously reviewed the original manuscript and to Sra. Helga B. de Schroth for typing the manuscript.

The Geological Society of America
Special Paper 467
2010

Mining and Metallurgy in Ancient Perú

by
Georg Petersen G.

translated by
William E. Brooks

INTRODUCTION

A vast number of worked sedimentary, igneous, and metamorphic rocks have been found at archaeological sites throughout Perú. Minerals were similarly used for gems, decoration, and other uses. Metals and fossils, as well as animal and plant material, were also used. The use of natural resources was more utilitarian than economic for the ancient indigenous groups, and many things that were utilized then are not in use today.

Authors who have made significant contributions to these materials studies include: Ahlfeld (1946); Alonso Barba (1640 [1967])[3]; Baessler (1906); Bingham (1948); Bonavia (1970); Ball (1941); Marshall (1964); Muelle and Wells (1939); Mujica Gallo (1959; 1961); Posnansky (1945); Rivero and Tschudi (1851; 1853); Schmidt (1929); Seeler (1893); Squier (1878); Uhle (1908); and others.

This work is a continuation of those studies and an attempt has been made to collect samples of the many mineral materials that were used in ancient Perú. A brief description of each is given, as well as its use, and locations where ancient miners might have sourced the mineral. This information was provided by interviews with archaeologists as well as from sources listed in the bibliography.

Contrary to what was believed earlier, all the mineral samples found at archaeological sites, with only a few exceptions, may be found at many locations throughout Perú.

Petersen G., Georg, 1970, Mining and metallurgy in ancient Perú (a translation by W.E. Brooks, 2010, of Minería y Metalurgia en el Antiguo Perú, Arqueologicas 12, Publicaciones del Instituto de Investigaciones Antropológicas, Museo Nacional de Antropología y Arqueología, Pueblo Libre, Lima, Perú): Geological Society of America Special Paper 467, 90 p., doi: 10.1130/2010.2467. For permission to copy, contact editing@geosociety.org.

CHAPTER 1

Minerals, Gems, and Pigments[4]

Several minerals have not been confirmed and have been omitted, such as the occurrence of ruby in the region of Cuenca, Ecuador, discussed by Juan and de Ulloa (1751) and an occurrence near Huancabamba (Steinmann, 1929/1930). Similarly, occurrences of crisoberyl ($BeAl_2O_4$) and euclase ($BeAlSiO_4(OH)$) (Tschudi, 1891, p. 143) have been omitted. It was not considered necessary to rectify erroneous determinations that were contained in the bibliography. It is sufficient to say that samples identified in archaeological collections as turquoise, topaz, lapis lazuli, and rose quartz may actually be crysocolla, jade, citrine, dumortierite, garnet, sodalite, fluorite, or other possibilities. The nomenclature and chemical formulas used herein are from Philipsborn (1967) and Lieber (1969).

Agate, SiO_2. Gray to white, may be found with basalts. Localities: Cerro de Pasco; Pomasi; Lucanas (Ayacucho); Veta Trinidad and Caylloma (Arequipa); Pasto Bueno (La Libertad); Huambo, Chota (Cajamarca); Parac, Huarochiri (Lima); Chala, Camaná; Carabamba, Otuzco (Raimondi, 1878).

Alabaster, $CaSO_4 \cdot 2H_2O$. White, fibrous. Localities: Pirin, Pusi (Lake Titicaca); Huamanga (Ayacucho); south of Cuenca (Ecuador) (Juan and de Ulloa, 1751). Mistakenly called onyx. In Quechua, *yurajrumi*. Also called *cachi* or *sal* (Alonso Barba, 1640/1967, p. 24).

Alum, see halotrichite.

Alunogen, $Al_2(SO_4)_3 \cdot 16H_2O$. Hydrosulfate of aluminum, Effloresces in mines from decomposition of silicic rocks and clays; forms crusts during dry periods. Shiny, silky, translucent, vitreous. Hardness: 1–2. Specific gravity: 1.6–1.77. Used as a color fixative for paints.

Amethyst, SiO_2. Color: dark violet, color is commonly due to iron or magnesium. Hardness 7. Specific gravity: 2.65. In Quechua, *laka* (from Yunga dialect). Well-formed crystals used as idols, in Quechua, *conopas*. Localities: Castrovirreyna; Chachapoyas; Mina Adán, Casma; Mina de Escoruro, Santa Isabel de Potosí, Bolivia.

Anthracite, (C). Black, vitreous, submetallic, resinous, conchoidal fracture, hardness 2–2.5. Specific gravity 1.6–1.7. Used for mirrors or beads for necklaces. Other names, *quillimsa* or *sansa* in Quechua (González Holguín, 1608), wood that burns without flame (Middendorf, 1890); *cisco*, in northern Perú.

Atacamite, $CuCl_2 \cdot 3Cu(OH)_2$. Oxidized copper mineral found in desert regions. Color: emerald green to dark green. Luster: vitreous to greasy. Hardness: 3–3.5. Specific gravity: 3.76. Localities: Nasca (Ica); Mina Canza (Ica); Pica, Tarapacá and Atacama (Chile); Cerro Verde del Tambo del Cortaderal between Islay and Arequipa (Raimondi, 1878); Acarí, Camaná; Tingue, Cerro Verde, Arequipa; Mina del Carmen, Cerro Trinidad, Arequipa; Mina Santa Rosa, Huantajaya, Tarapacá; Ilo, Moquegua; Chala, Camaná; Pampa Colorada, Hacienda Chocavento, Camaná. Other name, *lájsa* (Tschudi, 1891); however, not from Quechua.

Bitumen (Tar). Residue from hydrocarbons. Localities: northwest Perú; region of La Brea de Chumpi, Parinacochas; Pirin, Puno; many outcrops in the east. Found on the beaches at Talara; used as a glue for arrowheads, shells, and as mortar.

Brochantite, $Cu_4(OH)_6SO_4$. Alteration mineral, acicular. Color: emerald green to dark green. Luster: glassy. Hardness: 3.5–4. Specific gravity: 3.97. Localities: Canza (Ica); Cerro Verde near Tambo de Cortaderal between Islay and Arequipa (Raimondi, 1878); Chuquicamata (Chile).

Calcite, $CaCO_3$. Common mineral in rocks, ores, and veins. Color: white to gray. Luster: glassy. Hardness: 3. Specific gravity: 2.6–2.8. Effervesces in dilute hydrochloric acid.

Calinita, $KAl_3(OH)_6(SO_4)_2$. Alum or potassic alum. May effloresce from volcanic rocks, and alum-bearing slates. Hardness: 2–2.5. Specific gravity: 1.7–1.8. Color: white. Luster: vitreous. Astringent. Used as a color fixative or filler for paint.

Cardenillo, a copper carbonate, see malachite, $Cu_2CO_3(OH)_2$. Color: gray-green, green. Name in Quechua, *l'ah'sa*, which may also mean bronze. In powdered form, used as an offering in sacrifices, also called *ancas llimpi*, Inca *cardinillo*, *azul*, *llimpi*, and colored powder. These terms are rarely used in modern Quechua.

Cassiterite, SnO_2. Tin mineral may be found associated with pegmatites, placers, and hydrothermal sources. May have a variety of crystal forms (Petersen, 1965, figure 18). Color: black, brown, dark yellow. Luster: metallic. Hardness: 6–7. Specific gravity: 6.8–7.1. Related minerals: wolframite, zircon, garnet, and vesuvianite. Localities in Perú and Bolivia (see Tin).

Chalcanthite, $CuSO_4 \cdot 5H_2O$. Poisonous. Copper sulfate. Produced in desert regions. In Quechua, *ankas llimpi*, from *ankas* for blue and *llimpi* for color. Color: sky blue, blue-green. Luster: glassy to subtransparent. Hardness: 2–2.5. Specific gravity: 2.2–2.28. Powder from this mineral was used in sacrifices (Rivero and Tschudi, 1851).[5] Common name: *alcaparroza* or *caparroza*; in Bolivia, *piedra lipe* or *lipes* (Quechua); *llimpiyaj* (Alonso Barba, 1640/1967, p. 293–294), the generic name of *caparroza* or copper sulfate is *millo* or *millu* in Quechua. Other terms are *misi* or *sori*, the significance is not clear but might be related to *missi* or *mici*, words for the domestic cat and *sori* or *suri*, alpaca and ostrich, respectively (Lira, 1945; González Holguín (1608) or with suffix *mil'* which means to sicken.

Chalcedony, SiO_2. Banded quartz with a variety of colors. Widespread. Color: yellow, red, blue, green. Luster: glassy to greasy. Hardness: 7. Specific gravity: 2.65. Localities: Turco, Mina Cuprita (Bolivia); Pampa de Ica, Incapuquio, Toquepala, Desierto de Sechura. See also: jasper (blood-red). Found in Pajonal, Atacama (A. Vásquez de Espinoza, 1628/1942) and at Tiahuanaco (Bolivia) (Ahlfeld, 1946; Ahlfeld and Schneider-Scherbina, 1964).

Chalcopyrite, $CuFeS_2$. Copper iron sulfide. Color: yellow, brassy. Streak: black. Hardness: 3.5–4. Specific gravity: 4.1–4.3. Name in Quechua, *gualdo*, *waldo*. Localities: Morococha, Cerro de Pasco and many other mines in central Perú; Mundo Nuevo, La Libertad; Puno and in many mines in Bolivia.

Chenevixite, $Cu_2Fe_2^{3+}(AsO_4)_2(OH)_4{\cdot}(H_2O)$. Arsenate of copper with hydrated iron. May be found in the oxidation zone of polymetallic deposits. Sulfur arsenate with copper, enargite, or tennantite, in contact with the atmosphere; rare at depth (Goldschmidt, 1954). This is an arsenic compound that is stable in the oxidation zone in arid climates, but oxidizes in humid climates, dissolved by meteoric waters (Ginsburg, 1960).

Chenevixite may be massive to compact. Color: dark green to greenish yellow. Specific gravity: 3.93. Commonly found with malachite. Localities: Tintic (Utah, USA) (Klockmann and Ramdohr, 1947); Tsumeb Mine (Namibia, Africa) (written commun., Dr. Ulrich Petersen); Chuquicamata, Chile; and at Mina Cobriza, Rio Mantaro, Huancavelica.

Although not specifically mentioned, Raimondi (1878, p. 125) indicates arsenic of copper and hydrated iron in his samples (218, 219), on crystals of panabasa (tetrahedrite) and with stibnite or pseudo-limonite, from oxidation of panabasa, and still keeps tetragonal form; arsenic of copper from Cerro de Pucará, east of Lurín and Mina San Antonio de Morococha.

The minerals chenevixite and arsenic of copper-iron may, because of their color, appear to be malachite weathered from arsenopyrite; may have greenish streaks of arsenic with iron.

Chert (silex), SiO_2. Sand, flint, cryptocrystalline. Very common as concretions and may be associated with porphyritic intrusions. Color: white to dark gray, reddish. Luster: glassy. Hardness: 7.0. Specific gravity: 2.59–2.61. May be used to start fires. See: chalcedony and jasper.

At Punta Sal Chica, Tumbes, chert artifacts were found that appeared to be from broken nodules that had already been polished. The style of these fragments suggests that they are from the pre-Ceramic period. Wetzel (1939) studied the many pieces that were submitted to him in 1938 and found fossils that suggested a sedimentary origin, perhaps of Cretaceous age. He established a new species from the fossil evidence: **Chitodendrum peruanum**.

Chrysocolla, $CuSiO_3{\cdot}H_2O$. Copper silicate. Found as small, earthy exposures, also called *coravari* or *piedra verde*. Color: greenish, emerald green, blue-green. Luster: glassy to greasy. Hardness: 2–4. Specific gravity: 2.0–2.2. Streak: green to blue-green. Name in Quechua, *llanca*. Localities: Ate (Lima); Cansa (Ica); Cerro Verde (Tarapacá); Tingue (Ica); Cerro Verde (Arequipa); Acarí, Camaná, (MGI); Mina del Carmen, Cerro Trinidad (Arequipa); Huantajaya (Tarapacá); Mina de los Italianos, Cerro Pumahuin, Cajatambo; Pampa Colorada, Hacienda Chocavento, Camaná. Sometimes mistakenly called turquoise. An excellent example of an anthropomorphic figure made from chrysocolla was found at Pikillacta, Middle Horizon 2B (Ravines, 1970, p. 501b).

Chrysoprase, SiO_2. Chalcedony, quartz. Color: apple green, color from trace amounts of nickel. Hardness: 7.0. Specific gravity: 2.65. Luster: greasy. Localities: Ayacucho. (MGI)

Cinnabar, HgS. Color: vermillion, dark red, cochineal red, scarlet red, brownish red, salmon. Luster: metallic. Streak: scarlet red. Hardness: 2.0–2.5. Specific gravity: 8–8.2. Name in Quechua, *paria* (Cobo; Tschudi, 1891); *pari*, living red, ruby red (Lira, 1945); *pari* (Gorrión, undated); *pari huana*, flamingo (González Holguín, 1608); *pucca llimpi*, *pucca*, *llimpicuna*, *ychma*, *ichma* (Garcilaso de la Vega, 1609); *chama* (Morúa, 1925). Used as a pigment on murals and ceramics and to decorate gold masks. Also used in funeral ceremonies. Localities: Huancavelica; Chonta; Prov. Dos de Mayo, Huánuco, Santa Cruz (Dept. Ancash); Azoguine (Dept. Puno). Powdered cinnabar was also used in sacrificial ceremonies (Rivero and Tschudi, 1851) and at Pachacamac, cinnabar cosmetics were used for the living and the dead.

In a pre-Columbian cemetery, approximately 2 km north of Ocucaje (Ica Department), two shells of **Concholepas concholepas** were found that contained cinnabar that had been used as a cosmetic or paint (Fig. 7). During the Inca reign, it was common that the royal wives (*coyas*), princesses of royal blood (*ñustas*) and the women married to nobles (*pallas*) painted their faces with a red line from the eyes to the temples.

Yacovleff and Muelle (1934, p. 157) provided important information about the use and significance of cinnabar: "Cinnabar is used exclusively as body and face makeup, and all over for soldiers (Acosta, 1590); the material is called *llimpi*, but its use is called *embijarse* which is a hispanicized form of the native word referring to *bija* or *bixa* which refers to the red dye from the fruit of the **Bixa orellana** plant. This use was widespread in ancient South America, including Perú, where the plant was known as *achiote*. In the writings of González Holguín, *ichma* indicates "color of the fruit from a young tree" and *ichmakuni* means to color the face or to be achiote-colored (red-colored). Garcilaso de la Vega was possibly in error and confused the reds that the Indians used to paint their faces, which was cinnabar or *llimpi*, with the **Bixa orellana** or *ichama* also referred to as *ychima*, because cinnabar is not used to dye cloth. From the Spanish Chronicles, it is also important to note that a mineral dye, which is also red and for the same use, is called *paria* (Arriaga, undated). This means that among those things used for sacrifice, *paria* was a brightly colored powder similar to the vermillion powder that was obtained from the mercury mines at Huancavelica and similar in appearance to red lead.

A small bird with a brightly colored breast is also called *paria* (Tschudi, 1891) and perhaps there is a similar etymological association with the flamingo, or *parihuana*, which has beautiful, light-cinnabar-colored feathers.

Copiapite, (Fe, Mg)$Fe_4(OH)_2(SO_4)_6 \cdot 20H_2O$. Iron sulfate. Color: sulfur yellow, orange, green. Streak: yellow. Hardness: 2.5. Specific gravity: 2.08–2.17. Localities: Mirador, Ancash; Cerro de Pasco; Copiapo (Chile). Minerals with similar appearance: coquimbite, jarosite, and ochre.

Coquimbite, $Fe_2(SO_4)_3 \cdot 9(H_2O)$. Weathering product in desert regions. Color: white, light yellow, greenish, bluish, purple. Hardness: 2. Specific gravity: 2.1. Localities: Copiapo (Chile); Prov. de Castilla, Arequipa; Huacra, Yauli; Canta; Salpo, Otuzco.

Dumortierite, $(Al, Fe)_7(O_3)$ $[BO_3][SiO_4]_3$. Contact metamorphic mineral and also found in pegmatites. Fibrous. Used for the manufacture of ceramics. Color: dark blue, gray to brownish, reddish. Luster: silky. Hardness: 7. Specific gravity: 3.3–3.4. Occurrence: Cerro Verde, Arequipa (936, 946); about 2 km from Cucucha and 10 km downstream from Canta, Lima. Worked pieces in pre-Columbian tombs, for example: Zapallal, northeast of Carabayllo, Rio Chillón, Lima. Dumortierite has been mistaken for lapis lazuli.

Emerald, Be_3Al_2 $[Si_6O_{18}]$. Gem variety of beryl. May be found in association with granites and pegmatites; also in detrital deposits. Color: emerald green to dark green, sometimes greenish yellow to gray green. Partial translucence. Hardness: 7.5–8. Specific gravity: 2.63–2.80. Under ultraviolet light, natural emerald reflects a pale violet to rose color. Minerals that may have similar coloring include apatite, chrysoberyl, corundum, topaz, tourmaline, green fluorite, transparent jade, green beryl; colored with iron and chrome. None of these minerals has the same index of refraction, nor the characteristic inclusions, nor the specific gravity of emerald.

In Quechua:

khespi, *cauata, caguata, umiña rumi* (Santo Tomás, 1560)

umiña (González Holguín, 1608), precious stones in general

ccomir vmiña or *ccomir qquespi vmiña*

komer umiña, komer umiña rumi

qhespi, quespi, khespi, glass or thing that gives light

ccomer, komer, comer, green

In Aymara:

khespi kala, precious stone

l'iphiri or *l'iphil'iphiri kala*, brilliant stone (Tschudi, 1891)

tsokhña umiña, green gem

tsokhña khespi kala, green crystal (Tschudi, 1891)

khespi, qhespi, quispi, all bright stones, obsidian, or quartz (Torres Rubio, 1616)

In Yunga:

kauata, kawara, cauata, caguata (Santo Tomás, 1560)

The color green was highly regarded by the ancient Peruvians and this was true for gems as well as green rocks, all of which were referred to as *comer qhespi.* This generalization may have caused mistakes in some old texts regarding the occurrence of emeralds.

The only sources of emeralds in the Americas are in Brazil and in Colombia at the Muzo and Chivor Mines, approximately 100 km north and northeast, respectively, from Bogotá, Colombia. These mines have continually produced high-quality emeralds since ancient times. Colombian emeralds have long been used in trade and commerce. At the diggings near Cocló, Lothorp (1937, *in* Ball, 1941) found several emeralds, one of which was 189 carats and the other was 112 carats. Emeralds have been found in pre-Columbian tombs from Panama to Perú.

With regard to the reported occurrence of outcrops of emeralds in Ecuador, the only reference is from Pedro Cieza de León who traveled in Perú in 1548–1550. Cieza de León described in Chapter 1, from the first volume of Crónica General del Perú (1553), data from early in the Conquest about a discovery of emeralds in the Manta region, Ecuador. One of these emeralds, because of its size, was worshipped and called *umiña*. Pedro and Alonso Alvardo, upon arriving in Ecuador, found gold, silver, and a great quantity of emeralds. Antonio Vázquez de Espinoza (1628/1942 and 1948), who explored in Ecuador in 1614, confirmed that several mines with emeralds superior to the emeralds from Muzo, Colombia were near Puerto Viejo and the provinces of Las Barbacoas and Las Esmeraldas. Juan and de Ulloa (1751), repeated, as had other authors, references to Minas Mantas, Atacames, and Coaquis, and indicated that they had not been able to locate these emerald mines. On the other hand, Wolf (1892) questions the occurrence of emeralds in Ecuador and challenges the interpretations of previous writers by explaining that emeralds are not to be found in fluvial sands and that the mines did not exist. Finally, from historic documents and according to stories told by the soldiers, Wolf indicates that Alvarado's small band did not actually pass through Prov. Esmeraldas, but disembarked farther south, in Caraques Bay.

In Atahualpa's ransom at Cajamarca, the Spaniards seized a great quantity of emeralds. Padre José de Acosta (1588/1954) tells that after his return to Spain in 1587, the Spanish fleet brought back two large boxes of emeralds, each weighing approximately 45 kg; Melchor Verdugo, in a letter dated 8 March 1548, told his sisters that he had sent 22 emeralds, one of which was valued at 8,000 to 10,000 gold coins (Loredo, 1958).

In Perú, emeralds are to be found at Cerro Taquicacca, approximately 12 km from Chuquibamba (Cusco) and Acomayo (Cusco), however, this was unconfirmed (Steinmann, 1929/30). An emerald in the Museo de Geología (#145) has the notation "from Huacho." According to Srta. Angela Florez (Directora, Museo de Geología, Universidad Nacional de Ingeniería, Lima), this sample was given to Dr. Gil Rivera Plaza as a gift from the parish of Huacho and he did not wish to indicate the exact location.

Alonso Barba (1640, p. 27) said that from the beginning of the Conquest, many large and precious emeralds had been found with the Indians in Bolivia; however, Ahlfeld (1946), Ahlfeld and Muñoz Reyes (1955), and Ahlfeld and Schneider-Scherbina (1964) indicate that there are no emerald occurrences in Bolivia.

Fluorite, CaF_2. Hydrothermal or pneumatolitic origin. Color: light green, bluish, dark blue, rose, purple, violet, rarely without color. Hardness: 4. Specific gravity 3.1–3.2. Transparent to translucent. Localities: Cerro de Pasco; Huanuco; Ombla, Morococha; Pallasca, Panao (Nuanuco); San Geronimo (Huancayo), Santiago de Chuco; Yanacancha, San Marcos (Huari); Yauli. Fluorite artifacts found in pre-Inca tombs at Tiahuanaco (Ahlfeld, 1946; Ahlfeld and Schneider-Scherbina, 1964). This mineral is sometimes incorrectly called rose quartz.

Galena, PbS. Mineral frequently found in hydrothermal deposits. Color: lead gray, reddish. May contain silver. Streak: dark gray. Hardness: 2.5–3. Specific gravity: 7.2–7.58. Ancient Andeans knew of the importance of galena from smelting lead-silver ores. Name in Quechua, *suruche, sorojche, suruchi*, also the name used to describe a mountain sickness that affects those traveling in the Andes and may cause heavy breathing and heart problems (Lira, 1945). In mining, it means *suruchiy*, or to let something fall and leave the other part (Lira, 1945). *Sorojchi*, the name of a mineral compound of sulfur, iron, copper, pyrite, and marcasite. Ancient Andeans attribute the difficulty in breathing in the mountains to the presence of these metals (Middendorf, 1890). In the case of galena, the term roughly translates to "that which runs with silver during smelting." Specifically called *sorojche* if the galena crystals are small and presumed to contain silver; galena with large crystals and good cleavage is typically silver-poor, however, when the structure is fibrous, it may contain antimony and silver. According to Rivera Plaza (1947, p. 24), galena is common near Huaraz and in the Cordillera Negra: *chumbe* white or mottled white, sulfide of zinc and lead. Silver with or without lead may be referred to as *anco*, derived from Quecha *anku* meaning stringy, hard to chew or cut.

Garnet, general formula $X_3Y_2(SiO_4)_3$. Key: X = Ca, Mg, Fe, Mn; Y = Fe, Al, Cr, Mn. Garnets include magmatic as well as metamorphic varieties and were used as pharmaceutical preparations by the Inca (Carranza, 1922). The most important varieties include:

Pyrope, blood colored, hardness: 6.5–7. Specific gravity: 3.5. Localities: Acoria, Huancavelica. In 1954, hundreds of dark-red colored pyrope were found in Castrovirreyna (Cuchicancancha) and were on display at the Museo de Geología, Universidad Nacional de Ingeniería. May be confused with ruby.

Almadine, common garnet. Color: red. Hardness: 6.5–7. Specific gravity: 4.2. Localities: Chapi, Quilca. Grossularite, contact garnet. Color: white, greenish, reddish, cinnamon. Hardness: 6.5–7.5. Specific gravity: 3.5. Localities: Ate, Lima; Cerro Jato Viejo, Ricardo Palma, Lima; Cajamarca.

Andradite, contact garnet. Color: brownish, green. Localities: Antamina, Ancash; Morococha.

Collophane, contact garnet. Locality: Monterrico, Lima (Broggi, 1910).

Goethite, $HFeO_2$. An oxide mineral, hydroxide of iron with variable amounts of water, possibly with some manganese. Color: brown, to yellowish to black. Compact, nodular. Hardness 5–5.5. Specific gravity 3.3–4.3. See ochres.

Guano, (N, P_2O_5, K_2O), a complex organic product used for fertilizer. In Quechua, *wano* or *huano*, waste material from marine birds. Localities: found on many islands along the Peruvian coast. At the beginning of the 1800s, the accumulation of guano at the Chincha Islands was more than 40 m thick. Because of extensive use, the annual production of this natural fertilizer declined. The presence of many archaeological artifacts shows that the guano islands were visited during ancient time for celebration of rituals and for exploitation of the fertilizer for use on the mainland. Different authors have studied the chronology of guano production: Mochica age, Larco Hoyle (1945b, p. 13) described a ceramic container with a scene of one of the guano islands; Chimú age (Gonzales de la Rosa, 1908); Inca (Hutchinson, 1873). Kubler (1948) came to the conclusion that deposition of the guano began approximately 400 B.C. and that the Moche artifacts were from the 900s, the Inca artifacts from the 1400s, and the Colonial artifacts were from the 1600s. Steffen (1883) described the use of guano and other fertilizers used by the Inca.

Gypsum, $CaSO_4{\cdot}2H_2O$. Anhydrite, $CaSO_4$, an evaporite mineral. May be fibrous, frothy, fine-grained (alabaster), foul-smelling, crystalline, compact, earthy. Color: white, gray, reddish, brown, blue, black. Luster: glassy to silky. Hardness: 1.5–2. Specific gravity: 2.32. Localities: Anhydrite and gypsum occurrences are found in many parts of Perú, for example, Asia, La Banca, Anta, Cangallo, Chilca, Islas Chinchas, Cusco, Huacho, Huamanga, Mashuyaco, Moyobamba, Morropón, Otuma, Pachachaca, Yauli, Pasco, Mascate, Piura, Santa, Pampa Seca (between Ica and Pisco), Sechura, Tumbes, Lago Titicaca, Muni, Villacurí, Pisco. Name in Quechua, *pachas* or *pachach*. The ancient metallurgists used a mixture of clay and gypsum to make the molds that were used for making metal objects (Rivero and Tschudi, 1851, p. 185).

Halotrichite, $FeAl_2(SO_4)_4{\cdot}22H_2O$. Hydrated sulfate of Al and Fe. Fe alum, Pb alum. Color: white, grayish, apple green. Luster: silky. In Quechua, *cachina*. Used in solution as a color fixative in paints.

Hematite, Fe_2O_3. Common mineral with iron occurrences. Color: steel gray, black. Streak: red to dark red, blood red. Hardness: 5.5–6.5. Specific gravity: 5.26. Also see, pigments. In Quechua, *tacu* or *taco*, red earth or red iron oxide; taku, red-orange colored earth found in iron mines and used for pigment (Cobo, 1653, L. III, c. 9).

Hematite, specular, Fe_2O_3. Variety of red hematite. Frequently found with iron deposits. Color: steel gray to iron black. Streak: cherry red to brownish red. Hardness: 5.5–6.5. Specific gravity: 5.2–5.3. After working, has a black shiny surface. In Quechua, *huincho*.

Jadeite, Na, $Al(Si_2O_6)$. This mineral is associated with serpentitized gabbros. Color: Greenish white, white to dark green, translucent. Hardness: 6–6.5. Specific gravity 3.3–3.5. Also looks like nephrite. Some varieties of jadeite have been classified as turquoise. In Perú, a jadeite idol was found in Nasca (Museo Oro del Perú).

Jasper, SiO_2. Opaque chalcedony, associated with quartz porphyries. White to gray. In concretions as flint. Compact, very fine-grained. Color: blood red, yellow ochre, brownish, greenish. Hardness: 7. Specific gravity: 2.65. Quebrada Tinaja, Huarochirí; Huancayo; Parras, Cangallo. Pomasi, Lucanas (Ayacucho). Common. Variations include:

Black, Pumapampa, Recuay; Huancavelica. Also as slate or siliceous slate.

White, Pajonal, Atacama (Vázquez de Espinoza, 1628/1629).

Red, also at Pajonal; Huancavelica, Coracora, Parinacochas.

Jarosite, $KFe_2(OH)_6(SO_4)_2$. Oxidation product, may be clustered in crust-like outcrops near orebodies. Color: yellow. Hardness: 2–3. Specific gravity: 2.91–3.26. Similar in appearance to other yellow ochres.

Lazulite, $(Mg, Fe)Al_2(OH)_2[PO_4]_2$. Color: sky-blue, purple-blue, blue-white to white. Luster, glassy. Transparent along the edges. Hardness: 5–6. Specific gravity: 3.12–3.33. Similar appearing minerals include lapis lazuli, turquoise, sodalite. Localities: Perú, Huancavelica; Bolivia, common in tin-bearing pegmatites in the Cordillera; also Rio Challana and its streams (Ahlfeld and Muñoz Reyes, 1955).

Lazurite (lapis lazuli), $(Na, Ca)_8$ $(SO_4, S, Cl)_2$. Contact metamorphic mineral found in limestone and marble. Samples may also contain: lazurite, calcite, augite, hornblende and pyrite. Color: dark to light blue, violet blue, greenish blue, translucent along edges. Streak: light blue, variegated blue. Luster: glassy to greasy. Hardness: 5.5. Specific gravity: 2.38–2.42.

The blue color is due to the ultramarine molecule, $2Na_2O{\cdot}Al_2O_3{\cdot}SiO_2{\cdot}2Na_2S_3$. Pyrite ($FeS_2$) disseminated in the lapis lazuli may give it a golden tone. The blue color is affected by heat and weathering and the pyrite may decompose to brown iron oxide. The mineral decomposes in dilute hydrochloric acid and releases H_2S.

For a long time lapis lazuli has served as the primary material to make the pigment ultramarine and also for jewelry. Similar appearing minerals: dumortierite, sodalite, and turquoise.

Localities: Chile, Ovalle region, many occurrences of light-colored lapis lazuli, may have inclusions of calcite, also Atacama coastal region; Bolivia, Ayopaya region (Uhle, 1908), however, Ahlfeld and Muñoz Reyes (1955) do not mention any lapis lazuli occurrences in Bolivia; Perú, near Cusco, float of blue colored rock (Uhle, 1908, p. 95); Cerro Verde, Arequipa; probably identical to a sample of dumortierite (no. 936, 946); Ayucucho, large samples; Raimondi (1878) erroneously called it *lazulita*; also described in Canta. This sample probably came from an outcrop with dumortierite, from Cucucha, near Canta.

Lapis lazuli has been found as jewelry and as an ornamental stone in many pre-Columbian burials. According to O.C. Farrington (1903, *in* Ball, 1941) the largest artifact found at any archaeological site measured 61 × 30 × 30 cm. A special use of lapis lazuli for a lip adornment was found at the Chimú cemetery at Los Organos (Piura) (Petersen, 1955). At Tantaorco, near Orcasitas, right bank of the Huarpa, a side-stream of the Marañon, Tello (1940) found worked cylinders of lapis lazuli. In the old cemetery of Zapallal, near the Puente Piedra, Lima, blue float classified as lapis lazuli was found, however, this was likely dumortierite from the Canta region.

Magnesite, $MgCO_3$. May have yellow streaks, gel-like, formed during evaporation from magnesian silicates from igneous rocks because of acidic meteoric waters. Color: clear, white, yellowish, brownish. Luster: glassy. Hardness: 4–4.5. Specific gravity: 2.9–3.0. Localities: Mirador, Huaylas (Ancash). Used for figurines.

Magnetite, FeO, Fe_2O_3, or Fe_3O_4. Iron ore. Color: black. Luster: metallic magnetic. Hardness: 5.5. Specific gravity: 5.2. Localities: variety of iron occurrences. See Ch. 1: Iron. In Quechua, *huincho, wincho rumi*, *kisu*.

Malachite, $Cu_2(CO_3/OH_2)$. Hydrated copper carbonate. Oxide mineral associated with copper occurrences. Compact, nodular. Color: emerald green, green, dark green. Streak: light green. Luster: glassy-silky. Hardness: 3.5–4. Specific gravity: 3.95. When exposed to heat, water escapes and the mineral blackens. Reacts with acids and ammonia. May be polished. Similar appearing minerals: sulfo-arsenates of copper, chrysocolla, atacamite, and brochantite. Localities: Mina Posco Rico (MGI); Lauricocha (MGI); Yauyos (MGI); Mina Raúl, Mala; Acarí and in most copper mines. Name in Quechua, *ancas llimpi*, also blue powder, and Inca blue. Pre-Inca malachite artifacts were found in the ruins at Tiahuanaco, Bolivia (Ahlfeld, 1946; Ahlfeld and Schneider-Scherbina, 1964).

Melanterite, $FeSO_4{\cdot}7H_2O$. Hydrated iron sulfate. Vitriol of iron. Oxidation mineral. Astringent. Color: light green, yellow, brownish, wheat-colored. Luster: glassy. Hardness: 2. Specific gravity: 1.90. Water soluble. Barium chloride produces a white precipitate. Name in Quechua, *llasca* or *comer llimpi*, green powder. According to Rivero and Tschudi (1851), powdered melanterite was used for ceremonies and sacrifices.

Found in many mines along with pyrite, for example, Corte de Ladrones, km 52 of the Central Highway, barite mines (MGI); Cerro de Pasco (CR 222); Mina Santa Cruz (mercury), near Caráz, Prov. Huaylas; Cerro de Hualgayoc; Chonta, Prov. Dos de Mayo; Mina Raúl, Cañete (CP); Colquijirca, Pasco; Morococha, Yauli; Santa Rosa, Chilete Sunchubamba, Cospán (Cajamarca).

Iron sulfate is an acidic compound that was used for ancient metalwork and for gold-plating.

Niter (*salitre*). These salts are commonly mixed with sand and clay and are found in soils and rocks in desert regions of the Peruvian coast. In Chilca, soils may contain 2.5%–3.3% niter; Asnapuquio, Lima; Santa Elena, Virú; Lurifico, Guadalupe, Pacasmayo; also near *huacas* (holy places) and tombs. Name in Quechua, *ccolpa*, *kollpa*, *suka*, *suka allpa*. Niter was used as a filler for paints.

Nitronatrita (sodium nitrate), $NaNO_3$. Caliche. Uncolored or lightly colored. Luster: glassy. Hardness: 1.5–2. Specific gravity: 2.2–2.3. In Quechua, *collpa* or *kollpa*. Also called Chile saltpeter, a component of explosives and fertilizer, may also be used in glass or ceramic work.

Nitro (potassium nitrate), KNO_3. Found as an evaporite in desert areas. Uncolored to gray-white. Luster: glassy. Generally occurs with sodium salts. Hardness: 2. Specific gravity: 1.9–2.1. In Quechua, *ccolpe*, *kollpe*, or *cuca allpa*. May be used with salt and gypsum in paints and metallurgy, also used for gunpowder.

Obsidian. Natural glass formed by the rapid cooling of silicic volcanic rocks and even in thin-section, there are no crystals. Color: dark to black, transparent, dark green to dark gray. Luster: glassy, almost metallic reflection. Hardness: 5–5.5. Specific gravity: 2.45. Common in volcanic terrane. Obsidian degasses at 1000 °C to become pumice.

Name in Quechua, *quispi capa*, clear thing; *quispi rumi*, transparent rock, (Santo Tomás, 1560); *kespi*, transparent glass or crystal; *kespi rumi*, rock crystal (Middendorf, 1890); *quispi*, transparent crystal (González Holguín, 1608). Name in Aymara, *quispi* or *qhespi*, glass (Torres Rubio, 1616). Obsidian is sometimes called black agate or *aya collqui*, faded silver.

In Ecuador, the black variety of obsidian is called “piedra de gallinazo” or buzzard rock (Juan and de Ulloa, 1751). A special use of obsidian was as part of an *estolica*, or throwing device, shown in the Museo Oro del Perú (Display 7, no. 1163).

In one of the caves at Cerro Colorado, Paracas, Tello (1929) found a package of surgical instruments that contained obsidian knives with points shaped as if they had been used for blood-letting. Other instruments were for cutting tissue and other larger obsidian instruments were for cutting bone. At Cerro Los Cerrillos, to the west of the Panamerican Highway, to the south and about 10 km from the road to Marcona, were found a number of obsidian points that possibly indicate a workshop for obsidian processing (J. Fernandez Concha, 1960, oral commun.). Among the artifacts that were found during the excavation of Machu Picchu, Bingham (1948) found 29 fragments of worked obsidian that were possibly the primary material for making obsidian blades along with five ancient obsidian knives. Another knife was found that was made of chalcedony.

Localities: Puno, Lake Titicaca; Caylloma, Vitor, Arequipa; Parinacochas (Col. Servicio Nacional de Geología), Puquio, Lucanas; Nazca; Cerro Candela (Lima); Huanta y Pachitea (Huánuco) Ayacucho; Huamachuco, Moquegua, approximately 12 km toward Cerro Raul (J. Fernandez Concha, 1960, oral commun.); Palca (Departamento de Tacna), approximately 15 km to the east, at the base of the Huaylillas ignimbrite is lenticular obsidian (Sir John Wilson, 1963, oral commun.), Cerro Quispejahuanca 4884 m; approximately 25 km east-northeast of Castrovirreyna, and located near San Genaro, between Choclococha and Orococha lakes; comprises a volcanic feature that may be obsidian of andesitic composition. Ing. Mario Arenas studied the area and described the feature as andesitic or trachytic vitrophyre that was not obsidian and he also indicated that there was no obsidian in the nearby float (31 August 1970, written commun.) (MGI and CP).

According to Rogger Ravines (1968, oral commun.), at Quispisisa, near San Genara, there is an outcrop of obsidian that was exploited in pre-Columbian time as indicated by ancient mining tools and artifacts found nearby. It is likely that the obsidian artifacts found in ancient tombs in Paracas and Nazca were sourced from this outcrop. The samples that were obtained were of andesitic obsidian with poorly developed fluidal features.

In Ecuador, near Quito, there are obsidian outcrops (Juan and de Ulloa, 1751) similar to those at Guamaní, where obsidian was traded with coastal groups (Ball, 1941). At several archaeological sites in Bolivia, for example, Tiahuanaco, numerous obsidian artifacts have been found.

Obsidian is a very important artifact and may indicate the interchange of goods. Obsidian has been found in many pre-Columbian burials that are distant from outcrops of obsidian, for example, those outcrops at Ocucaje and Toma Luz.

Ochres and Pigments

Ancient writers have described the colorful paintings that were found in pre-Columbian temples and other sites. Padre Cobo (1653/1956, Chapters 9, 10) refers to the orange, yellow, and brightly colored earths that are associated with the iron mines and that are also used for paints. The name for these in Quechua is *taco* or *tacu*, but these are commonly known as hematite, red ochre, or iron oxide. There is a wide range of colors that may be produced from these substances such as yellow, canary yellow, orange, blue, white, sky blue, brick red, black, brown, red, rose, blood red, dark and light green, and many other variations. These paints may be monochrome or polychrome and are dominated by red, yellow, and white with lesser use of green and blue. Cobo also mentions a yellow earth that is used by the painters that is called ochre, and in Aymara, *quellu*. Another type of yellow earth is called *pitu*. A yellow powder, possibly deep yellow ochre is called *karwamuki* in Aymara (Tschudi, 1891) and in Quechua, *kkarwa* or *muki.*

According to Morúa (1925) the ancient Peruvians worshipped the sea and gave sacrifices of red ochre and flour from white corn.

For ancient man, the primary material for earth colors were the powdered oxides, hydroxides, and carbonates of copper, iron, and manganese as well as clays and other natural earth substances such as:

Substance	Color
iron-rich clay	yellowish green
atacamite	bright green
azurite	light blue
brochantite	light green
calcite	yellowish white, white
cinnabar	red, vermillion
copiapite	orange, green-yellow
coquimbite	yellow
sphalerite	yellowish white
goethite	yellow, brick red, dark brown
hematite	red, brick red, blood red
jarosite	yellow, brown
melanterite	light green, yellowish
malachite	blue green
obsidian	gray green
orpiment	ochre, yellow, light chrome
pyrolusite	blackish brown
realgar	orange chrome
turquoise	blue green
wad (manganese)	dark brown
gypsum	white

At the extensive pre-Columbian ruins along the left bank of the Rio Nazca, near the Cahuachi Hacienda (Strong, 1957), a package was found that contained a fine powder composed of dark brown iron hydroxide. This was possibly used as an ochre for decoration of Nazca ceramics that were made in the region. Small adobe structures were also found which were interpreted as ovens that were used for ceramic production.

PAINTINGS AT SACSAHUAMAN

In the Muyujmarka sector, Sacsahuaman, Cusco, Valcárcel (1935) found different colored earths that were analyzed by J.A. Paresa and O. Baca (Madrid) and D. Karateeff (Mina La Oroya). Their analyses indicated: azurite, cinnabar, malachite, orpiment, and realgar. The Paresa and Baca study indicated that these materials were obtained in their natural state and, because of their toxicity, were likely not touched by human hands. Karateeff confirmed the presence of kaolin and Valcárcel supposed that the colors had something to do with ceramic manufacture. Fester and Cruellas (1934) indicated that cinnabar and azurite were not used in ceramic production because they reacted or were chemically changed during firing. They determined that at the textile plant at Paracas, insect-derived cochineal was used, as well as indigo and certain plants of the **Rebulnium** species, but there was no use of mineral pigments. According to Valcárcel, azurite, malachite, and powdered turquoise were used in making the pigments that were glued onto *keros* (wooden cups). These were mixed in a small cup of white alabaster, in a box used for pigments, and kept in sealed containers—the colors vermillion, sky blue, and chrome yellow were used so that the color would be more transparent; it is likely that he was also describing azurite, cinnabar, and orpiment. This receptacle was described by Valcárcel (1935) as having been made from alabaster. It had six cylindrical receptacles that contained three colors: vermillion, sky blue, and chrome yellow, with a color in each of the cylinders. These cylinders were covered with a tightly fitted alabaster lid.

PIGMENTS FROM PARACAS

In several funerary bundles from Paracas, tanned, deer hide pouches were found that contained pulverized material that was examined by Fester and Cruellas (1934). They found brilliant vermillion; a yellow-white powder that possibly contained zinc, lead, arsenic, and tin; a dark green to grayish powder, similar to green chrome, that contained atacamite, and copper chloride; a gray to pearlescent powder with some brown that contained zinc, iron, magnesium, calcite, and quartz; an orange powder with cinnabar probably from Ica, also atacamite; a blue gray powder with azurite, minor malachite; a dark red powder, granular, perhaps iron oxide, containing abundant quartz, iron oxide, and very little aluminum. Yacovleff and Muelle (1934) provided these databases on comments from ancient historians who thought that the pigments were of organic origin. These data showed that during the Necropolis period (500 B.C.), lead from galena and zinc from sphalerite were used for pigments.

According to Posnansky, the pigments that were applied to religious vessels (*kkeru* or *kero*) were obtained from minium (lead salts), antimony oxide, iron oxide, pulverized turquoise, and malachite. All of the pigments described were used in their native state and were pulverized; however, the pigments were altered by firing. These mineral pigments could also have been used on wooden objects or for cosmetics (Yacovleff and Muelle, 1934). The vessels were originally ceramic and were from the Early Tiahuanaco period (A.D. 750–1250); during the Inca period and at the beginning of the Colonial period, many wooden vessels were used, some with modified form and design.

PIGMENTS FROM PACHACAMAC

Gypsum and other natural earths that had previously been calcined provided a variety of colors based on the temperatures used. In order to fix the colors, plant extracts such as **Gigante** (***Cereus* sp.**) cactus gel and glue derived from the *sapodilla* (***Capparis scabrida***) plant were used. Muelle and Wells (1939) studied residual materials from paints and pigment powders, found at Pachacamac, that permitted them to better define the techniques and materials used for painting and decorating buildings and ceramics (Table 1).

POLYCHROMATIC PIGMENTS FROM VIEJA LIMA

In the ruins of the ancient city in the Huatica Valley, which includes the Maranga, Pando, and Aramburu Haciendas, murals on the walls of the Huaca Concha were described (Bonavia, 1962). These were brush-painted with yellow, orange, and white with red stripes showing zoomorphic and human beings. These paintings are from the Inca period.

POLYCHROME MURALS FROM PANAMARCA

The murals at Pañamarca, Hacienda Capellanía, Nepeña Valley (Ancash) were researched by Bonavia (1959) and he concluded that they were from Phase IV of the Moche epoch or possibly from the beginnings of Phase V. The paintings were made using a base that was composed of a mixture of calcite with iron oxide from nearby sources. Analysis of the pigments indicated four combinations:

- Calcite with limonite and hematite: cream white, gray-white, dark orange, dark red, red ochre;
- Calcite with hematite: dark sky-blue, light gray, black;
- Calcite with magnetite: light orange; and
- Calcite with limonite: light orange.

Onyx, SiO_2. Variety of chalcedony. Onyx limestone is a fine-grained, translucent limestone ($CaCO_3$).

Opal, $SiO_2 \cdot H_2O$. Common opal. See: Jasper. Amorphous, compact. Color: yellowish, white, purple, brown, greenish. Luster: vitreous. Varieties may be milk white to fire red. Hardness: 5.5–6.5. Specific gravity: 1.9–2.5. Localities: Caylloma; Jeronta, Nasca; Lampa; Puyo, Parinacochas; Yauli. Found in tombs in Ancón, Lima, also known as opal pearls and described by Reiss and Stübel (1887).

Orpiment, As_2S_3. Arsenic sulfide, commonly of hydrothermal origin. Non-metallic. Color: lemon yellow to orange yellow. Subtransparent. Luster: greasy to pearl-like. Streak: lemon yellow. Hardness: 1.5–2. Specific gravity: 3.49. Localities: Acobambilla (Huancavelica); Huanta (Ayacucho); Huancayo; Huarochirí; Ica; Rangra; Mina Virginia, Yauli (Junin). In Quechua, *hambi* and a variety of other names, see realgar.

Pedernal (flint), SiO_2. Rock commonly used as a cutting tool. See: chert, chalcedony, and jasper.

Pentasulfide of arsenic, As_2S_5. Pentasulfide of arsenic does not constitute a specific mineral series and is obtained as a precipitate at temperatures below 500 °C. Color: looks much like orpiment but a much lighter yellow. Muelle and Wells (1939, p. 82) indicate that pigment sample 9, from Pachacamac, was a bright yellow powder and considered that its yellow color was due to the high content of sulfur. This sample seemed related to orpiment, As_2S_3, however, analysis showed that arsenic and sulfur were present in proportions indicative of pentasulfide or As_2S_5. In the example of the yellow pigment from Pachacamac, it is likely that this is probably a naturally occurring mixture of mono- and trisulfides of arsenic.

Pyrite, FeS_2. May be of hydrothermal or sedimentary origin. Also called "Inca stone" or "fool's gold." Color: yellow, brass yellow, golden yellow. Luster: metallic. Streak: greenish black. Hardness: 6–6.5. Specific gravity: 5.0–5.2. For its uses in gold and silver work, see Chapter 4 (Petersen, 1969b).

Name in Quechua, *quillo*, *carhua*, *carayani.qui*, or *quilloyani.gui* (Santo Tomas, 1560); *quarwayani* (Ricardo, 1586); *ccar huayan qquelloyan*; *quelloccarhua* (González Holguín, 1608); *carhuanuqui* (Rivero and Tschudi, 1851); *karhua* (Middendorf, 1895); *kkarwa*; *kkarwayay* (Lira, 1945); *jellu, karwa, jarwa*; *jarwayay, jelluyariy* (Perroud and

TABLE 1. PIGMENTS USED BY ANCIENT PERUVIANS

Color	Fester and Cruellas	Alstrom	Karateef	Parera and Baca
Red	Cinnabar	Cinnabar	–	–
Rose	Cinnabar	Cinnabar	Cinnabar	Cinnabar
Orange	Cinnabar	Realgar	Realgar	Realgar
Gray/brown	Sphalerite	–	–	–
Gray/green	–	Obsidian powder	–	–
Earthy white	Sphalerite	–	–	–
White	Sphalerite	–	–	–
Light yellow	–	Orpiment	Orpiment	Orpiment
Yellow ochre	–	–	Orpiment with iron oxide	–
Dark green	Atacamite	Malachite	Malachite	–
Blue	–	–	Azurite	Azurite

Note: From Muelle and Wells (1939).

Chouvenc, 1970); *carhuanuqui*, *carhua llimpi*, (Rivero and Tschudi, 1851). Used as a dust or powder during sacrifices.

Pyrite objects have been found in pre-Inca tombs at Tiahuanaco (Ahlfeld, 1946; Ahlfeld and Schneider-Scherbina, 1964) and widely used for mirrors (see Chapter 10, Mirrors, and Fig. 13).

Pyrolucite, MnO_2. Gray. Mineral found in the oxidation zone along with psilomelene (manganese). Color: black. Luster: metallic gray. Streak: black. Hardness: variable. Specific gravity: approximately 5. Localities: Lucanas; Pampas; Tayacaja (Huancavelica); Puno; and many other occurrences.

Quartz, common, SiO_2. Found in many geological environments. Color: white, milky, opaque. Hardness: 7.0. Specific gravity: 2.65. Localities: Pasto Bueno (La Libertad); in many of the mines in the Andes, also in veins in metamorphic terrain as vein quartz. In Quecha: *kispe*, *cuarzo*, *quijos*. From Alonso Barba (1640, p. 24), "…called *quijos*, the class of pebble found with gold and silver and other types of metal, and very hard and strong, the veins are strengthened." Rivero y Ustariz (1857, p. 288) "…these are quartz rocks, some brown, but white is more common, and have gold and other metals." Rivera Plaza (1947) "…gold-bearing quartz." The word *cachi* is also used for amorphous quartz, for barite, and whatever other white matrix is found with metals (Rivero y Ustariz, 1857, p. 277).

Quartz, rock crystal, SiO_2. Uncolored quartz, glassy, translucent, may be cloudy to milky. Luster: glassy. May be of hydrothermal or pegmatite origin. Hardness: 7.0. Specific gravity: 2.65. Localities: Casapalca, (Lima) (MGI); Mina Adán, Casma, Ancash (MGI); Museo Larco Herrera, Lima. Numerous fragments and worked pieces from tombs near Trujillo; also in the Museo Oro del Perú (Sr. Mujica Gallo, Lima); large variety of necklaces with beads of rock crystal. Name in Quechua, *quespi, cristal*; in Yunga and Quechua, *laka*, found in well-formed crystals, also as clear amethyst (Tschudi, 1891).

Quartz, rose, SiO_2. Rose-colored quartz, almost transparent. The color is due to trace amounts of manganese which is sensitive to light and heat. Hardness: 7. Specific gravity: 2.6. Localities: Viso; Matucana, Lima. Used for necklaces (Museo Oro del Perú). Quartz, smoky, SiO_2. Rock crystal, brownish to black, semitransparent. Color may be due to impurities or radioactive decay from inclusions. Mina Adán, Casma, Huaylas, (Ancash).

Quartz, yellow rock crystal (citrine), SiO_2. Color: yellow to brownish, light wine- colored, honey- to gold-colored. Hardness: 7. Specific gravity: 2.6. Mistakenly called topaz; there are various yellow-colored gems, but citrine has a lower index of refraction. Localities: pegmatite veins in Cerro de Illescas, Sechura. Various samples were collected by Dr. Ulrich Petersen in 1960 at the base of the hills between Reventazón and Salina Cerro.

Realgar, As_4S_4. Hydrothermal origin. Color: yellow to orange-yellow. Transparent to translucent. Luster: non-metallic, resinous, greasy. Streak: orange. Hardness: 1.5–2. Specific gravity: 3.56. Used for "royal yellow" pigment in ancient times. Localities: Anamaray, Quichuas (Cajatambo); Cerro de Pasco; Mina Cuarenta, Huarochirí; Morococha; Pachacha, Yauli. Very toxic.

Names in Quechua generally indicate its poisonous nature, *hambi, hambij, pozoña*; *huanuy'nin* (Santo Tomas, 1560); *huanuchik caman hampi* or *mink hampi*; *kañuyhampi* or *huañuciccuc*; *anuy* or *millay* (González Holguín, 1608); *hampi* (Middendorf, 1890); *wañu*, *wañuy*, *wañuy wañuy*; *wañukk*, *wañurkkoy*; *wañuchichikukk* (Lira, 1945).

Red earth. Engel (1958, p. 47) made several observations on the use of red earth for pre-Ceramic period artifacts and he indicated that it was typical of the pre-Ceramic to find blocks of red earth (iron oxide). These are found in various sites along with batanes and grinders, and also are found in tombs in Asia along with Chavin-like ceramics. It is not known what the powdered red mineral [*Translator's note:* cinnabar? See Appendix, "Cinnabar, Mercury, and Small-Scale Gold Mining"] was used for. The material was usually found in bags or baskets in dwellings and tombs in Culebras, Rio Seco, and in Asia. In whatever pre-Ceramic site, manos and stone grinding tools stained with red minerals are found. No skeletons with this red material are found in the tombs, however, we have seen that bodies are often painted. It seems that the material was used for clothing applications. A "bolsa del curandero" or medicine man's bag was also found in a well in Asia. It contained various items such as red paint, a type of grass or mate known as *secana* and *añaz*. Charm stones and polished river stones were also found, all of which were common in the Culebras tombs.

Salt (halite), NaCl. Common salt is an evaporite that commonly forms in shallow basins. Color: diaphanous, grayish white. Luster: glassy to greasy. Hardness: 2. Specific gravity: 2.1–2.2. Common salt is an important mineral for human consumption in the present and in the past. Name in Quechua, *cachi*, *cachi chajra*, and *cachi chakra*. Name in Aymara, *hayu*. Localities: near Cusco; Junín (pre-Columbian ceramics of San Blas, Nomland, 1939), Yurimaguas, Huallaga, and other coastal sites (Benavides, 1968).

In prehistoric time, salt flats were exploited along the coast and in the Titicaca Basin. It is very likely that salt was found near Pilluana along the margins of Huallaga and salt came from numerous salt water springs along the eastern flank of the Andes. Salt was widely known and used in ancient times, however, the Spanish writers mention only a few of the salt occurrences used by the ancient Andeans. In his writings, Alonso Barba mentioned Mina San Cristobal de Achocalla, near Tumaquita; Yullona, a saltwater spring; and three salt flats at Caquigora, Prov. Pacajes and at Curaguara de Carangas, all of which are near Potosí, Bolivia. Cieza de Leon mentions salt occurrences near Tumbes, Puerto Viejo, and the salt flats of Huacho (Huaura) where pre-Columbian ceramics are also found. Condesuyos and Andesuyos are also included. P. Lizárraga writes of salt at San Sebastián and also as you leave Cusco traveling toward Collao, there is a free-flowing salt spring with a large evaporation tank that dates to Inca times which yields white salt within a few days. The nearby area has been divided into plots in order to share the wealth of the salt flats. Figures of birds, lions, tigers, and other animals were carved from the salt and sold (Lizarraga, 1908, p. 81). In the writings of Gutierrez de Santa Clara, salt occurrences are described at Collique, Trujillo, Jauja, and San Miguel. Juan and de Ulloa (1751) also describe salt at Chilca.

Evidently there were many more salt occurrences that were used by the ancient Andeans. There are documents showing their claims to these areas that date to Inca times and are now kept in the National Archive.

Salt earth (*tierra salobre*). In Quechua, *cachima*. With nitrate and sodium chloride. Used as an extender for paints. Also known as saltpeter, niter.

Sodalite, $Na_8Cl_2(AlSiO_4)_6$. Mineral associated with volcanic rocks. Color: white, gray, greenish, gray, light to dark blue, sea blue. Luster: glassy to greasy. Hardness: 5–6. Specific gravity: 2.2–2.4. Localities: Castrovirreyna, Huancavelica (Perú); Cerro Sapo, Tultani (in the hills near Palca), Prov. Ayopapa, Cochabamba (Bolivia). Sodalite may be found with nepheline syenite intrusions in Paleozoic schists. Samples may contain galena, chalcopyrite, pyrite, and sphalerite. These were mined in pre-Inca times at Cerro Sapo (see map and photo 121, Ahlfeld and Schneider-Scherbina, 1964; Ahlfeld, 1946; Ahlfeld and Muñoz Reyes, 1955) and at Pachacamac and Ancon, Lima (Reiss and Stübel, 1880; Uhle, 1908).

Sphalerite, ZnS. Zinc sulfide, ore of zinc. Hydrothermal origin. Color: amber, yellow, almost uncolored, white, light brown, greenish red. Hardness: 3.5–4. Specific gravity: 3.9–4.1. Localities: Mines of Perú, central. Common name: *chumbe* (Rivera Plaza, 1947).

Stannite, $Cu_2(Fe, Zn)SnS_4$. Commonly found with copper and silver minerals. Also found with copper and tin-bearing veins. Common ore in Bolivia. Color: olive to steel gray. Streak: black. Hardness: 4. Specific gravity: 4.3–4.5. See Chapter 3, metals.

Sulfur, S. Product of volcanic gases. In Quechua, *sillina* or *sallina rumi*. Color: yellow, orange to light brown, waxy. Hardness: 1.5–2. Specific gravity: 2.05–2.09. Localities: volcanoes in the south, Misti, Ubinas, and the Tacna region. May also occur as an alteration product from gypsum.

Turquoise, $CuAl_6(OH)_8(PO_4)_4 \cdot 4(C_20_4)_4$. An aluminum copper phosphate, a common mineral but rarely as a gem. Color: sky blue transitional to gray-green, opaque, sometimes with brown-black veinlets. Color not affected by artificial light. Hardness: 5–6. Luster: waxy. Similar appearing minerals are amazonite, chrysocolla, jade, lapis lazuli, lazurite, odontolite, and serpentine.

Localities: Nevada, New Mexico, and California (United States) are the main producers of turquoise in the Americas. Mining of these sources began around A.D. 500. Turquoise was used for necklaces, many of which were found in pre-Columbian burials (Ball, 1941).

In Perú, occurrences are near Huari, between Huanta and Ayacucho. Turquoise is found mainly as rounded stones that are greenish blue, light green, to almost white. Turquoise may be found in loose earth, however, this is not where it naturally occurs. These occurrences are likely related to working of the stone by ancient Peruvians.

It was not possible to study Raimondi's collection. The samples that he described were possibly from a pre-Columbian workshop. Samples obtained from the area were chrysocolla.

At Pikillajta, approximately 27 km from Cusco, 40 figurines and a stone idol with the green-blue color of turquoise were found. Analysis by Dr. Karateef indicated 2%–6% copper and it reacted to phosphoric acid which indicated turquoise.

In Bolivia, Barba (1640/1967, p. 27) said that turquoise was found in Atacama, Dist. Cobija, Prov. Potosí; one sample was as large as a coin; local people brought these well-finished stones which were also used for necklaces. There were also stones that had been worked into the shape of war clubs. Ahlfeld and Muñoz Reyes (1955, p. 148) indicated that samples from Tiawanaku were malachite, chrysocolla, or green chalcedony. Turquoise was rare. No turquoise has been found in place in Bolivia and the turquoise was likely from Perú or coastal Chile.

In Chile, in the Atacama and at Chuquicamata, Prov. Coquimbo, during Inca times, the people found much turquoise (chrysocolla) that was used for jewelry-making (Solari, 1967, p. 53).

Wad (manganese), MnO_2. Mineral may form as a result of weathering. Color: black, dark brown, to blue-black. Streak: black. Luster: metallic. Hardness: 1. May be found with pyrolusite, psilomelane, and in iron-bearing horizons.

White earth, (*tierra blanca*). In Quechua, *kontai*. Also, marl or chalk. May be mixed with common salt and used to polish metals. Still used in northern Perú for metalworking.

MISCELLANEOUS (PEARLS, MOTHER OF PEARL, MOLLUSKS, ABALONE, SHARK TEETH, AND SILICIFIED WOOD)

Mother of pearl, from the nacreous interior of the abalone shell or other mollusks, is known in Perú and these mollusks are called *conchas perleras*.

Genus: **Pteria**
Pteria sterna

The species from which mother of pearl was originally described were known as **Avicula sterna** (Gould, 1851); **Avicula peruviana** (Reeve, 1857); **Pteria peruviana** (Reeve and Dall, 1909); **Pteria sterna** (Gould, 1851; Smith, 1944). For another description, see Olsson (1961, p. 146). Size variable, but commonly, 90–100 mm in length, 46–88 mm in height, and 30–43 mm in diameter. Distribution is from California, USA, to the northwest coast of Perú and has been found at Máncora, Cabo Blanco, Lobitos, Paita, and Bayovar.

Genus: **Pinctada** (**Margaritaphora**).
Pinctada mazatlanica (**Hanley**)

Also includes: **Meleagrina mazatlanica** (Hanley, 1856); **Avicula barbata** (Reeve, 1857); **Margaritiphora** (**Pinctata**) **mazatlanica** (Hanley and Smith, 1944); **Pinctada mazatlanica** (Hanley et al., 1943/1945), also see Olsson (1961, p. 147). Found from California, USA, to northwest coast of Perú; Paita; and the Galapagos Islands. Color: typically white to silvery, nacreous. Hardness: 2.5–3.5. Several varieties are known:

Specific gravity:

black pearl	2.65
clear pearl	2.65
Venezuelan pearl	2.70
cultivated pearl	2.75

Intensive harvesting of the mollusks in the past has left large mounds of shells at some of the beach localities given above. In northern Perú, these shells are described as black or white mother of pearl.

Other pearl-shell mollusks include: **Semele solida**, an exceptionally thick-shelled bivalve with a nacreous interior that provides excellent mother of pearl (Rivera Plaza (1947, p. 28) and the locally well-known *lampa* (**Pinna sp.**) which also may have a nacreous interior (Koepcke, 1951, p. 13). Name in Quechua, *tsuroy* (Tschudi, 1891, p. 145) also *churu*, *churo* or *choro*; *piñi* (Middendorf, 1890), a word that is a neo-Quechuismo that describes "droplets, glass pearls, used for necklaces and bracelets." In pre-Columbian time, examples of pearl have frequently been found. These examples are commonly dirty, weathered, and fragile because of partial decomposition in the burial. Pearl necklaces are found in many museums and were used by the Chimú. There are several examples on display in the Museo Oro del Perú, Lima.

Santa Cruz Pachacuti Yamqui (1927 revision, p. 182) tells that Pachacutiyngayupangui "…arrived at a jungle island, where mother of pearl, called *xchuruymaman* was found; also was found another variety called *omiños* (*umiñas*)." It is possible that the island Lobos de Tierra was described. Since the arrival of the Spaniards, there had been extensive harvesting of pearl along the coast of Venezuela. In a document from Corregidor Hernando de Zuñiga dated 24 April 1577, pearl beds are described at Puerto Viejo, La Plata, Cabo de San Lorenzo, Bahia Caraques, and Manta (Ecuador). More information from this document is given in Morúa (1925, p. 187). Pearl fishing was known near Talara and Punta Aguja (Sechura). Dall (1909) indicated that toward the end of the 1800s, a foreign company found 200 pearls worth about $2,000 and a small black pearl, worth about $400, was also found. Pearl harvesting ended around 1901 because of low returns and the destruction of the beds. The large accumulations of mollusk shells show the intensity of harvesting in the past.

Chile. There is some information about pearl fishing in Chile during the beginning of the Colonial period: "Pearls were harvested along the coast of the Atacama, and in Mejillones, were taken from the oysters, and then sold in the Provinces. It is very common to find pearls when the oysters are washed for cooking or eaten raw" (Alonso Barba, 1640/1969, ch. XV, p. 27).

Spondylus princeps. This species was described as **Spondylus princeps** (Broderip, 1833); **S. dubius** (Broderip, 1833), **S. leucacantha** (Broderip, 1833); **S. unicolor** (Sowerby, 1847); **S. pictorum** (Sowerby, 1848); **S. crassiquama** (various authors, however, not described in Lamarck, 1819). Description: see Olsson (1961). Discussion: See Petersen (1969a). Size: length 130–150 mm; height 135 mm; diameter 79 mm. Distribution is from Panama to northeastern Perú, occasionally as far south as Paracas according to Dr. Rosalvina Rivera C. (oral commun.); Zorritos; Caleta Sal.

According to Engel (1958, p. 46), "… counting beads that used tubes or discs of bone and shell are found in the pre-Ceramic period artifacts of the Peruvian coast." It is easy to see that **Spondylus** was revered in ancient Perú because the red-purple necklaces were found at many archaeological sites. **Spondylus** was widely used during the Chavin period from the northern coast to Paracas in the south. **Spondylus** was found in ancient burials in the Chira Valley; Yécala, Piura; Lambayeque; Chiclayo; Cajamarquilla, Rímac River; Miraflores, Lima; Ancón (Reiss and Stübel, 1880). Literally hundreds of **Spondylus** were excavated from these archaeological sites.

The interior of the **Spondylus** and its spines, when new, were used for making beads for necklaces (Quechua, *chakira*) along with gold, shells, and polished pebbles, and the shell was also used to make figurines (Petersen, 1969).

There are many names, for example, in Quechua, *mullo,* coral or pearl (Santo Tomás, 1560); *mullo*, colored shell, *chaquira*, or earth coral (González Holguín, 1608); *mullu,* colored shell, coral (Middendorf, 1890); *mullu*, rose coral (Lira, 1945); *mullu chakira*, seashell, coral, (Perroud and Chouvenc, 1970). Researchers do not distinguish the species, and it seems that *mullu* can only be **Spondylus** and not ancient or modern coral. In many museums, necklaces described as being made from "coral" are made from **Spondylus**.

Examples of **Spondylus** found in tombs at Puntiudos and La Serena (Chile) were brought from Panama (Iribarren, 1962).

Strombus. A spectacular example of **Strombus galeatus**, a large marine gastropod, with carved figures, was found in 1937 near the Chiclayo air base. It was used as a musical instrument, likely for ceremonial or religious use. During the Colonial period, the ancient Peruvians called the gastropod trumpets *pututu* or *wailla kepa* (Tello, 1937). Name in Quechua, *pututu*, shell trumpet; *wailla* or *huaylla*, dance; *kepa* or *qquepa*, trumpet. Tello interpreted the decoration on the sample as Chavin and said that another horn, also Chavin, had been found at Punkuri, in the Nepeña Valley. The same species of gastropod was found in Moche burials (Larco Hoyle, 1945b).

OTHER MOLLUSKS FOUND IN ANCIENT BURIALS

These include:

Conus sp.	Yécala, Piura (Petersen G., 1969)
Arca sp.	Yécala, Piura (Petersen G., 1969)
Mytilus sp.	various locations

Shells of **Mytilus edulis** and other mollusks were used as spoons or containers. At the necropolis at Ancón, Lima, shells filled with cinnabar were found (Reiss and Stübel, 1880). In Quechua, *churo*, *churu* or *choro* and in Aymara, *ch'uru* or *'qeso*, however, these names were sometimes used for all shells. Shells were found also at Churubamba and Churupampa in fossil beds along with other gastropods. In 1802, the town of Choropampa, in Cajamarca, achieved scientific fame because of exploration by Alexander von Humboldt in the region. Humboldt (1849, p. 343; 1876, p. 559) indicated that to the west of Purgatorio, in a hilly area known as Choropampa, near the stream, Chiquera, were fossil beds. The name of the area indicates the presence of abundant fossils that were well-known to ancient Peruvians. In colloquial Peruvian Spanish, the prefix *choro* was a "Quechuismo" that indicated shellfish such as oysters or clams, especially the **Mytilus edulis**, which was a preferred food source in northern coastal Perú. **Mytilus chorus** was another food source.

Concholepas concholepas bruguiere. Two samples of this gastropod were found in a pre-Columbian burial approximately 2 km north of Ocucaje on the slopes of the Ica Valley (Fig. 7). As a side note, these shells were also used as palettes and some contained cinnabar. According to Dall (1909), the distribution of these gastropods included the Chincha and Mollendo Islands in southern Perú to the Magallanes region; also including the western coast of Mexico. This species was commonly called mule-foot or *pata de burro* in southern coastal Perú and was sometimes used as a food source. These gastropods were found at archaeological sites in the Ica and Nazca Valleys and were abundant also at Cahuachi and Estanquería. The name Estanquería is also used and refers to the place where forked posts were placed in rows along the expansive hillside. The presence of **Concholepas concholepas** at these sites, some 45 km from the Peruvian coast, indicates that this gastropod was a widely used food source.

Shark teeth. Engel (1958) found a length of cord composed of shark teeth at the pre-Ceramic Asia archaeological site which dates to 1300 B.C. Use of shark teeth is also known in Central America and elsewhere. For example, at the Joá site in Canton Jipijapa, Province Manabi, Ecuador, Holm (1969, p. 5) found 24 shark teeth, some of which were fossils which had been used for various purposes. Additionally, the presence and use of shark teeth provides biological information as well as help in understanding the technology of the time. This is because shark fishing is both dangerous and difficult because the shark, upon its death, must be filled with an air bladder, or otherwise floated, or the carcass will sink.

The fossil shark teeth found at Joá are from **Carcharodon megalodon**, an extinct species from the Late Pliocene. Teeth from modern sharks are from **Carcharodon carcharias**, a Pacific species. Two shark tooth fragments were excavated from a trench and 18 were excavated from nearby burials. One of the fossil teeth measured 10 × 12 cm, weighed 30 g, and had the appearance of a winged hatchet. Smaller shark teeth were used for amulets or good luck charms. The Joá site is from the Bahia culture (500 B.C. to A.D. 500).

The frequency of finding fossil shark teeth in ancient burials in Perú is related to the abundance of shark teeth found in the Miocene-Pliocene strata in the northwest and south-central coastal areas of Perú.

Whales. In the pre-Ceramic period sites at Río Seco (Lima), large vessels carved from whale vertebrae have been found (Engel, 1958).

Fossils. As a scientific curiosity, it is worth mentioning that ancient Peruvians did not only decorate modern gastropods with gold and silver, as can be seen in the Museo Oro del Perú (Vitr. 24, 2904, 2914–2917), but they also collected fossil gastropods. For example, a Cretaceous **Trigonia sp.** is also on display in the Museo Oro del Perú.

Bezoar stone. In ancient times there was a great attraction for amulets and charms that, according to superstition, were protection against sickness, misfortune, and also brought good luck. Such objects were generally made from a variety of rocks, for example, the green andesite from Yécala, Piura (Petersen, 1969a). Its name in Quechua, *il'a* or *illa*.

Bezoar stone belongs to this group of rocks which are generally known as good-luck charms, but the name given is not correctly used with an inorganic object such as a rock, but bezoar stone is a concretion that may be found in the intestines of many animals and birds. One of the favorite types of this specialized stone is obtained from a deer or *taruca* (**Hippocamelus antisensis**) and was used by ancient Peruvians as a good-luck charm or a cure for a hangover. The name in Quechua, *kiku* or *quicu*, indicates an intestinal stone used as a talisman. These stones are composed mainly of magnesium carbonate and calcium phosphate.

CHAPTER 2

Ornamental and Industrial Stone

CONSTRUCTION

In ancient Perú, construction material, other than adobe, was either loose stone obtained in the field or quarried blocks. A variety of rock types were used for the construction of temples, forts, dwellings, and aqueducts. These include:

Igneous Origin

Andesite (green, black, brown)
    Sacsahuamán, Pachacamac and numerous other sites.
Basalt
    Tiahuanaco, Sacsahuamán.
Dacite porphyry (var. colors)
    Sacsahuamán, Ollantaytambo, Tiahuanaco.
Rhyolite (gray, white, red)
    Pachacamac, foundation of Mamacona Temple, canals, aqueducts at Cumbemayo (Tafur, 1950; Petersen, 1969b).
Andesitic tuff, trachyte (var. colors)
    Tiahuanaco, Sacsahuamán, Cusco, Coricancha.

Among the rock samples collected by A. Stubel in December 1876 at Tiahuanaco, Bergt (1894) identified the following: andesite with biotite, pyroxene, and tridymite; pyroxene andesite with olivine; andesite with amphibole and quartz; and pyroxene andesite. The rocks at Tiahuanaco could be subdivided into silicic intrusive rocks (Paleozoic); intermediate composition intrusive rocks such as granites, granodiorite, quartz monzonite (Mesozoic); intermediate composition extrusive rocks such as dacite and andesite; mafic extrusive rocks with a composition between basalt and andesite; and trachytic tuffs (Kitte *in* Mille and Ponce Sanginés, 1968).

The generalized timeline for construction at Tiahuanaco:

Epoch I, II	Formative
Epoch III	A.D. 133–374, use of sandstone, founding of the city
Epoch IV	A.D. 374–724, use of andesite and dacites for stellae, portals, and other uses of dimension stone

River stones and volcanic rocks such as rhyolite, andesite, and ashflow tuff were worked by hand and used for dimension stone that comprised the main construction materials used for the funeral towers at Acora and Sillustani, Lago Umayo (Puno Department), and other sites (Valcárcel, 1935; Vasquez, 1937; Pardo, 1942). The age of many of the funeral towers is uncertain; a large number are from the Inca time and others date to A.D. 400–1200 (Tiahuanaco period). See the section on adobe and sandstone.

Rivero and Tschudi (1851, p. 293), describe stone huts found near the hills near Clustoni lagoon (Puno Department) as having unique construction. It is unclear whether these huts were dwellings, or storehouses for grain or potatoes, or perhaps tombs (considered the most likely), and are therefore called *huacas*. All of those that we have seen were constructed with limestone, sandstone, and mica schist, with the windows about a foot high and divided with rock frames and covered with straw or rock fragments similar to those seen at Humalies. Stone huts or towers with similar construction are along the road from Lampa to Puno.

With respect to the construction materials used for ancient tombs, Tschudi (1891) indicates that the name for these features, which are commonly found along the Andean cordillera, is *matsai*, or "Indian tomb" and comes from the Yunga (Mochica) language. In Quechua, the tomb is called *ayawasi*, place of the dead, or *ayapuh'ru*, simply meaning grave. A grave excavated in sand or soil is called *imawi* (from *ima*, to hide); an underground tomb, lined with rock, for the elite, is called *kal'ka*, from Quechua *kal'ka* meaning a "great rock"; a large, above ground tomb is called *amayuta*, from Quechua and meaning "body" and may be derived from *aia* or *uta*, meaning something covered; a tomb constructed of stone or adobe in the style of a stone tower may be referred to as *thul'pa* or *asanko* and is likely derived from the Quechua word, *isanca* or *isanko*, meaning a large basket made of wicker. These sorts of baskets are woven and designed to carry large loads, vases, or the dead in a crouching position and the basket also serves as a coffin for the burial.

Caverns used for burials are abundant in the necropolis at Canta. The interiors are lined with stone and larger rocks and are shown in the illustrations by Villar Córdova (135, p. 145). Ancient Peruvians lived in rock huts, or *chujilla*, also referred to as house-tombs, or *kullpi*.

Sedimentary Origin

Sandstone, yellow, green, red
    Lake Titicaca; funeral towers.
Arkose, quartzite
    Tiahuanaco; Los Organos (Piura).
Sandstone, greywacke
    Tiahuanaco.
Limestone
    Generally Cretaceous. Large blocks are used as foundations at Pachacamac; also used for murals and stairways at the Temple of the Sun; at Sacsahuamán; Collcapata; in

the Plaza of San Cristobal (Cusco) where the walls are Greek-styled and use limestone that is yellow on the surface (Rivero and Tschudi, 1851).

Marble, onyx (stalagmites)
Carabamba (Otuzco).

Metamorphic Origin

Schist, dark green
Used in a variety of constructions.

STATUES, STELLAE, MONOLITHS, IDOLS, AND OTHER PURPOSES

Igneous, metamorphic, and sedimentary rocks were used for ancient sculptures and were generally obtained from surface exposures. Larger blocks were quarried.

Basaltic andesite, green. Amuleto de Yécala, Piura (Petersen G., 1969b); grinding bowls and knives, Machu Picchu (Bingham, 1930).

Basalt. Tiahuanaco, used for monoliths, mortars, and bowls.

Steatite (soapstone). Talc, serpentine. Stone bowls used by the Chavin (Museo Oro del Perú, Lima). Reproductions of steatite cups from the north coast of Perú with Cupisnique or Chavin designs (Lothrop et al., 1959) and are also in the Robert Woods Bliss Collection, Dumbarton Oaks, Washington, D.C.

Schist with mica and chlorite. A total of 165 pieces of various sizes were found at Machu Picchu (Bingham, 1948), three of which were found in a cave with pre-Inca objects. Most were disc-shaped and measured approximately 3.5 cm in diameter; however, two partially-worked pieces were found that measured 14 cm in diameter. All were of the same color. The smaller discs were interpreted as accounting pieces and the larger ones were likely used as lids for pots in which *chichi*, a corn-based liquor, was made. Additionally, 42 oblong pieces and 19 triangular pieces, with perforations, were found. The perforations suggest that the pieces may have been used as amulets. The age of these pieces is probably pre-Inca. Some stone objects are similar in form to bronze knives and cutting tools, however, they are usually smaller. Bingham considered these to be offerings to the god of metallurgy with the hope that these stone objects would result in perfect bronze castings. Middendorf (1894, p. 389) indicated that among the Chimú, it was believed that "Apart from religious objects, there existed among the mountain dwellers a number of diverse idols made of metal, wood, ceramics, or stone. These were small and likely used as protection against bad luck." A small bowl found at Machu Picchu was made of schist and may have been used as a small mortar for hand use.

Granodiorite, granite. Statues at Sechin and other sites along the Peruvian coast; carved for use as *stellaes* at Castillo de Chavin de Huantar, for example (Tello, 1929) and at Huamantambo and other sites in the Andes (Kroeber, 1944).

Graywacke, metamorphosed dirty sandstone with a clay matrix. A rounded cup was found at Cusco (Rivero and Tschudi, 1851).

Red jasper. A very heavy, well-made cup of red jasper with native iron as adornment, location undisclosed (Rivero and Tschudi, 1851, p. 321).

Jade. Metamorphic rock with fibrous aggregates. Emerald to apple-green and translucent in the margins. Hardness of 6.5 and specific gravity of 2.97–3.0. This material was prized in ancient times to make religious and other artwork. Jade is known in Venezuela where it was made into thin slabs that were perforated and used as necklaces. Gives off a metallic sound when struck. Phonolitic slabs have occasionally been found in northern Perú. Tschudi (1891, p. 145) believed that these were made of Peruvian jade during the Inca period based on a reference from Santa Cruz Pachacuti (1927, p. 183), who described in the Chimú world, a *huaca* that held a stone bell. Tschudi indicated that the ringing stone slabs should not be confused with the "miracle bells" which were blocks of diorite found at the base of Eten. Middendorf (1894, p. 389) observed that large stones were placed at the entrance to Eten and none were permitted to pass without giving a prayer. On a hill near the gate to Eten were two stones on a narrow base that gave such a metallic sound. Another term, *alek pong*, meaning the stone of the chief, was derived from *alek* (chief, leader) and *pong* (hill) (Zevallos Quiñones, 1947).

Andesite, green. Varieties of this type of rock crop out throughout the Andean cordillera. Colors range from green, to blue, to black. Used for a variety of purposes.

Porphyry, variety of colors. Used for bowls and other applications; a crude idol of green porphyry was found near Cusco (Rivero and Tschudi, 1851, lam. XLIV).

Sandstone. Found at the Timana ruins, an altar used for sacrifices (Rivero and Tschudi, 1851, lam. IIIL).

Limestone. Light bluish limestone used for the Statues of Taraco and other sites near Lake Titicaca (Kidder, 1943, p. 16, lam. I-III).

Marble, veined. Brownish cup, with yellowish veinlets described by Rivero and Tschudi (1851). Also used for mouth decoration, gray. In Guarani, *tembeta* describes a rock to be inserted in the lower lip. Outcrops near Cajon del Rio Campanario, Coquimbo, and Ovalle Department (Chile). Considered to be pre-Inca (Latcham, 1927).

Volcanic rocks, obsidian. Used for knives and other tools at Machu Picchu, Paracas, and other archaeological sites along the coast.

Slate, with mica or talc. Metamorphic rock, greasy to the touch, light to dark green, gray, to white. Luster, satinlike. Hardness: 1, easily scratched with a fingernail. A. Cucchi (Petrographic Lab, Cerro de Pasco Corporation, La Oroya) described a sample under the microscope as fine-grained, with aligned muscovite, sericite, and talc. Iron oxide associated with relict biotite, sparse chlorite. Sample was from the northeast of Cerro Amotape (Tumbes) where there are also Paleozoic slates, phyllites, and schists. Associated talc may be used as tailor's chalk.

Also found associated with Permian-Carboniferous through Devonian rocks in the Cerros de Amotape, Tumbes. Color is bluish black, used for necklaces and earrings. These artifacts were from a pre-Columbian ceramic assemblage near Malval, Rio Tumbes.. At Tiahuanaco, green slate was found that was possibly from Cerro Chilla (Ahlfeld, 1946; Ahlfeld and Schneider-Scherbina, 1964).

Serpentine. Metamorphic rock formed from mafic igneous rock. Color: dark to light green, gray-green. Found near Mina Gertrudis, Morococa, and in other Paleozoic terrain.

ARTIFACTS AND TOOLS

Many types of igneous, sedimentary, and metamorphic rocks were used in the production of artifacts and tools. These were usually not quarried, but were selected from surface exposures, or streams, and were chosen for their hardness.

Andesite, Granodiorite, Granite, Porphyry, and Diorite

These rocks were preferentially used as sling ammunition, weights for fishing nets, weights for weaving yarn, balls with or without grooves for twine, tools in general (hammers and hatchets), arms (clubheads, clubs), batanes, and other domestic use. A collection of tools and domestic utensils that were pre-Ceramic were from El Estero, to the east of Lobitos (Piura). Andesite, sandstone, quartzite, limestone, granite, and slate had also been used. Worked granite was used for a large cup, or pot, which was 20–24 cm in diameter. This pot was likely used for cooking or boiling water and was heated by putting hot stones, which had previously been heated in an open fire, in the pot. During research at Machu Picchu, hundreds of stone hammers and pebbles of diorite were found. In Cusco, a stone hatchet of green amphibolite, or possibly slate, with hornblende, was found (Rivero and Tschudi, 1851, lam. XXXIII). A club from the Peruvian coast, with a head made of diorite, Cusisnique style (Chavin de la Costa), is shown in Lothrop et al. (1959, lam. CXX).

Gneiss. Near Punta Aguja, locally called Mal Nombre, and Punta Nunura in the western part of the Cerros Illescas (Piura), Kostrinsky (1955) found the site of a fishing village and a cemetery, however, no ceramics were found. Only scarce pieces of worked containers made of a bluish stone were encountered. One of these containers had interesting markings and decorations. Christensen (1951, p. 46) studied that site in 1950 and found a cemetery separated from the rest of the town. It appeared to be quite ancient and did not have any ceramics. Bowls produced from nearby gneiss were decorated with precise designs and had been placed on the faces of the dead.

Basalt. An example of a basalt scraper with a stone shaft was described from the Nazca period. In a cemetery, Cabezas Achatadas, in one of the lower valleys of the Rio Majes near Camana, Disselhoff (1969b, p. 390) found very primitive hafted basalt scrapers that were enigmatic, especially given the absence of Nazca period ceramics and the abundance of brightly colored, well-woven textiles.

Sandstone, fine-grained. These rocks were used as abrasives, and quartzite was used for tools found at Yécala (Dept. Piura) (Petersen, 1969b).

Quartz sandstone. May be green when freshly broken and yellow on the surface which shows the effect of weathering. Used for knives and for polishing, found in the burials at Yécala (Piura).

Black chalcedony. This material was generally used to polish or burnish other materials.

Silicified Clay, Limey Clay, Silicified Slates

These generally dark-colored, sedimentary rocks have a hardness of 3.5–5. These have been worked to points of different sizes and forms and were used for a variety of projectiles. Such objects were found at Sechin, Chavin, Ticapampa, the lower Rio Santa Valley, and Chancay (Muelle, 1957); at Cusco, half-moon shaped knives of slate were found with Killke ceramics, while at Chavin and Chancay, red and white styles were found; various *manos* of slate were found at Ancon (Lima) (Reiss and Stübel, 1880). Research of pre-Ceramic sites by Engel (1958) along the Peruvian coast showed that from 4500 to 1900 B.C., a variety of rocks were used for making tools. In some cases, the lithology of these was unclear because they were simply referred to as "stone." The different types may be classified as follows:

Polished stones—for jewelry: necklaces of semi-precious stones, lapis lazuli (lazurite), serpentine, and turquoise. Also as stone jars or sometimes for grinding stones. Found at Los Chinos, Las Haldas, Huaca Prieta, Culebrias, and Asia. In many cases, the beads may be rectangular or disc-like, with a drilled hole.

Worked stones—for *batanes*, found in many pre-Ceramic sites.

Ordinary sedimentary rock—sandstone, worked and used as a weight for spindles.

Basalt—used for medium-sized knives, and larger pieces were used for pounding. Found at Los Chinos, Culebras, Rio Seco. Also used for points and found at Wankarani, south of Tiahuanaco, and glassy basalt points at Querimita (Ponce Sanginés, 1970, p. 29, figs. 16, 17).

Quartz, chert, obsidian—used for knives, scrapers, points, and formed by flaking. Found near Otuma, Boca del Rio Ica, San Nicolas, Ocona, Cabeza Larga, and Paracas.

Fossilized wood—also used for knives, scrapers, and points.

Stones were also used for domestic utensils, tools, and were found at archaeological sites in Chile (Medina, 1952):

Sandstone, as the vessel at Casa Blanca
Alabaster, container for cinnabar
Tabon marble, sculptures
Micaceous schist, chisels from Los Ulmos, Valdivia
Rock with talc or jasper, vases from Batro, Panama, Prov. Curico
Jasper, containers for powders
Granite, chisels from Ovalle and Llanquihue
Porphyry, figures, sculptures, hatchets, chisels
Volcanic rock, obsidian, for knives and other cutting uses

Quartz, Slate, Flint, Obsidian, Crystalline Quartz, Rose Quartz, Opal, Onyx, Topaz, Turquoise, and Others

According to Posnansky (1957), points and lance tips of these materials have frequently been found at Tiahuanaco. The forms may be different, and sizes vary from 6 to 10 mm. All were fabricated by using percussion. The Museo Diez de Medina has an excellent collection.

The Chilean historian Jose Toribio Medina described the importance of these pieces and their money-like importance (Posnansky, 1957). In particular, milky quartz was used as a type of pre-Columbian money. Other minerals were used as well. Heliotrope, a type of chalcedony, also called bloodstone or red jasper, was also important. One heliotrope sample that was 6 cm in length, and perforated, was found in a tomb along with other colorful stones. These were not thought to have intrinsic value, however, the perforation gave value through its usefulness. The perforated pieces could be strung together, which would prevent loss, and they were then used as a necklace to indicate elite status or wealth of the owner.

Porphyry, red. Red porphyry from Paracas was also used for points. These have been found in Paracas and also in burials near Ica and Ocucaje.

Lutite, quartzite, chlorite schist, feldspar, andesite, basalt, granodiorite, and rhyodacite. Near Aya Orjo (Ayacucho), Bonavia (1960) found nearly 50 mortars which were classified by Juan Ayza as follows: 17 of andesite, 7 of basalt, 6 of rhyodacite, 4 of quartzite, 1 of lutite, 1 of granodiorite, 1 of feldspar, and 1 was chlorite schist. A number of *porras* or clubheads of similar composition were also found.

Quartzite was used for Wankarani agricultural tools such as hoes which were found near Joya, Bolivia. Other agricultural tools were found along with a large stone mortar (Ponce Sanginés, 1970, p. 42, figures 18, 19).

QUARRIES, BUILDING, AND CONSTRUCTION MATERIALS

The technical aspect of quarrying dimension stone and other construction materials, as well as transportation of the materials, has been discussed by Acosta (1588), Ahlfeld (1946), Posnansky (1945), Schmidt (1929), and Squier (1878). For extraction, an area was cleared and cuts were made in the stone in order to introduce wood. After the wood was thoroughly wet, it began to swell and put pressure on the rock, thereby breaking the rock and allowing large blocks to be quarried. For examples, blocks of igneous rock that weighed a few hundred tons were found at Tiahuanaco, and limestone blocks that weighed 350 tons were found at Sacsahuamán. At Tiahuanaco, Acosta (1588) measured a 11.5 × 5.5 × 1.8 m block and said that there were many more of that size and larger in the walls at Sacsahuamán.

Of equal importance are the distances over which such heavy blocks were transported. Squier (1878) described a 1.5-km-long quarry road that was used to transport the volcanic rocks used for funeral towers in Puno. Schmidt (1929) indicated that blocks of basalt and other volcanic rocks were transported a distance of 30 km from the quarry to Cusco. Studies by Posnansky (1945) concluded that mainly sedimentary rocks were used during the first Tiahuanaco period. These were red sandstone blocks that cropped out near Desaguadero and were brought along a 25-km-long road south of Tiahuanaco. Dark basalt was brought from the Copacabana Peninsula using large rafts for transport across Lake Titicaca. Posnansky thought that some of the volcanic rocks had come from quarries more than 60 km away. The famous Tiahuanaco monolith was made from trachyte and measured 4.08 × 2.18 × 0.46 m. In 1882, Chalón (1882) found a stonecutter's workshop, as had Rivero and Tschudi (1851, p. 232–234). Andesitic blocks used at Tiahuanaco came from Cerro Kapira or *Ccapia* (Isthmus of Yungay) which was 57 km away (Bergt, 1894).

Transporting blocks of such size and weight is a significant engineering project that required ropes made of maguey (**Agave americana**), rollers, logs, and manpower. At Ollantaytambo, huge blocks of porphyry had to be lowered approximately 600 m from the quarry to the construction site in the valley below (Squier, 1878; Schmidt, 1929).

Aside from the cases given, it is important to recognize the civil engineering required for extraction and transport of the hundreds to thousands of blocks of normal size that were used in the construction of public buildings as well as the organization of the workforce. Unfortunately, no studies exist that permit estimates of the volume or weight of the dimension stone that was quarried, moved, and used in the construction of the ancient Peruvian monuments.

Transport of the dimension stone and other construction materials is but one part of construction. The other important part is placement of the stones. The exact methods that were used to construct the temples, forts, and bridges remain unknown. However, human strength was an important resource as there were no beasts of burden to move the construction blocks which were 3 m^2 and larger. The blocks were seated using bitumen (tar) or lime. A dirt ramp was constructed next to the building and the ramp was used to raise the building stones for the next level. Apparently, construction was completed using only ramps as there is no evidence for the use of hoists, winches, or pulleys. An unknown, but vast number of workers accomplished the construction (Fr. López de Gómara, 1552/1954, I, p. 330).

OTHER MINERAL MATERIALS USED FOR CONSTRUCTION

Unconsolidated geologic materials such as sand, gravel, clay, mortar, and plaster are an integral part of construction, are used for ceramics, and are commonly used near the occurrence of the material.

Sand—Fine- to medium-grained sand is used in the preparation of clay for ceramics and this material is obtained mainly from river deposits. Name in Quechua, *tiu*, *ttiu*, *aq'qu*, *acco*, or earth powder (Middendorf, 1890); in Amarya, *acu* or *challa*.

Gravel—One of the ingredients used in plaster to cover cyclopean walls, in Quechua, *silla*.

Soil—Composed generically of diverse materials and used as fill in walls. Type area, from Pucallpa, called "red earth." Name in Quechua, *pacha* or *allpa* and in Aymara, *pachacha*. Normally light colored.

Mud—Alteration product from lutites, slates, and marls and may be produced by dissolving these rocks in water. In Quechua, *saña* (Middendorf, 1890), or *turo*, *tturo* and type area may be Turuncunca, from *turo* meaning clay and *cunca* meaning disaggregated. In Aymara, *ñeque*, derived from Ocoñeque, Rio Quiton.

Marl—Gray-white clay that easily forms mud and used to degrease wool. Name in Quechua, *ch'ako*, also *llanca*. Also called washing stone/rock. Variety called, in Quechua, *kontai* or *ccontay* (Middendorf, 1890) and in Amarya, *llanca*, *llank'a* or *parpa* is also gray-white and may be used as chalk. In Lambayeque, Piura, and Tumbes, jewelers use a special type of marl to clean and polish metal, called *kontai*.

Clay—There is a large number of clays, all produced from marine, lacustrine, or terrestrial sedimentation, all having different purity and petrographic characteristics. There are no specific indigenous terms for the types of clay and the terms vary from one region to the other. Also, there is no study of the clays used for the manufacture of ancient ceramics, therefore, the discussion is general.

Plastic clay—Referred to as edible clay or marl, commonly white-gray, with a clay odor, and sticks to the tongue. Name in Quechua, *pallpa*, *chaco*, *ch'aquo*, a white chalk; in Aymara, *p'asa*. Ancient Andeans, for differing food needs, as in other cultures, also ate clay (Mejía Xesspe, 1931; Horkheimer, 1960). This edible clay is sold in Arequipa and comes from Chupa and Huajchani Patambuco, between Crucero Alto and Poto. It is generally prepared in the shape of a man, an animal, or small rectangles and eaten as a treat, sometimes with cooked potatoes (Rivera Plaza, 1947, p. 23).

Altered rock—A selvage of clay or a talc-like layer associated with mineralized veins that formed from alteration of the host rock by hydrothermal solutions. Name in Quechua, *llinque*. The same Quechua word is used to indicate the clay layer found at the base of alluvial gold deposits and above the underlying slates. This relationship is seen in the glaciofluvial gold deposits at Nevado Ananea (Poto region) and also in alluvial gold deposits along the west slopes of the Andes in the Sandia region. Occasionally this type of clay is found along faults, as gouge, and, in Quechua is called *yusca*. In Aymara, *llinqui*, *yusca*, *llusca*, *lluchca*, *lluskay*, meaning slippery (Middendorf, 1890).

Plaster—There are several different ideas about the use of plaster and mortar in ancient Perú. Ancient buildings such as palaces, temples, baths, aqueducts, funeral towers, murals, bridges, and buildings in general were constructed from unfinished or finished stone and float and set in place using mortar. Certain parts of roadways were repaired using rock materials.

Walls of unfinished stone—In some cases, unfinished blocks of rock were placed on one another with or without plaster or cement. Name in Quechua, *pirka*, *tica*, *pircca*, meaning a rock wall; *pircacuni-gui*, to build. In Aymara, *pircatha*. To seat the blocks, a sandy clay was used as mortar. If the mortar was very plastic then straw or other plant material could be easily added which would prevent contraction of the mortar when dry.

In construction, using worked blocks of volcanic or sedimentary rocks was preferred, because these could be placed in such a way that the joins were almost invisible. Usually, only the exterior portion of the block was finished. A very thin layer of cement made of a mixture of oily, sticky material was used to set the block in place. The interior of the wall was filled with ordinary materials. Oily mortar or bitumen (asphalt, as it was called in Colonial time) was also used.

Gypsum and calcium cements—In a few cases, calcium or gypsum mixed with crushed rock gave a very firm cement. Name in Quechua, *iscu*, *isku*, *yzcu*, *ysco*, calcium; *pachas* or *pachach*, gypsum. In Aymara, *catani*, *katawi*, or *qatawi*, calcium.

Ceramic clay—Material especially for ceramic work. Name in Quechua, *mittu*, or *mito*. Ceramic clay, which became plastic with water added, was usually a mixture of kaolinite, montmorillonite, and quartz and may also include sand, limestone, iron oxides, and other impurities. The color of the raw clay varies depending on the other mineral components: finely disseminated pyrite gives a dark blue to black; iron oxides give green; hydrated iron oxide, in the framework of the clay, gives red to yellow, when disseminated, gives bright red. So that the clay dries without cracking, the material must contain 18%–48% clay, such as porcelain or kaolinite, and 12%–24% montmorillonite. There can be a wide variation in the amount of the components and there are only a few sites from which clays can readily be extracted and used for ceramic production without additional components. In places where clay has been obtained from transported material such as river clay or silt, the impurities consist of different sizes of sand and mica flakes that may be seen in the finished Chimú pieces from Tumbes. Approximately 50% of the clay material consists of SiO_2. All the pottery was very porous which is useful only in a few domestic pieces. Therefore, the ceramic is covered with a slip or coating that is impermeable. Examination of ancient ceramics shows that the early pieces were poorly made in comparison to later ceramic work. Depending on firing in a reducing or oxidizing environment, significant color variations were given to the pieces. For example, clays with abundant iron changed color during firing to an intense red and the presence of manganese gave black. Clays with a high percentage of kaolinite gave a yellow-white color. The immense quantity of Peruvian ceramics in museums and collections show that in pre-Colonial time, mining and use of non-metallic mineral resources resulted in a large volume of ceramic pieces.

Toma Luz Center

Approximately 50 km south of Ica, on the left bank of the Rio Ica is Toma Luz, which is marked by several huts. The exact location is shown on Carta Nacional 1:100,000, Hoja 30-1, Lomitas. On the archaeological map of the region (Pezzia, 1970) the area is shown as more densely populated than it really is. The archaeological site, Toma Luz, is essentially two areas that are separated by low hills and sand dunes.

The first area is near modern dwellings along the banks of the river that, even in the dry season, has running water. Along the road to the south in the direction of Hacienda Ullajalla, for a distance of 200 m and 100 m wide, the low hills are littered with ceramic fragments that indicate the presence of an important workshop. Along both sides of the road are low adobe walls which were once dwellings. The adobes measure 55 cm in length by 25 cm in width and 12 cm in height and were covered with mud or clay plaster. These dwellings were used as rooms for the ancient workmen.

The second area is found approximately 200 m to the north, toward Pampa El Cacique, and is an area of irregular topography with elevations up to 700 m in the north and approximately 200 m toward the south. This is an important ancient ceramic work area that is significant for its size and age. The location of this workshop is important because of the availability of fuel from *algarrobo* (**Prosopis limensis**) and *huarango* (**Prosopsis chilensis**), abundant water, abundant clay, with minor sand, found a distance of less than 2 km away in the valleys to the east. At this location are outcrops of the Miocene Pisco Formation and abundant material from this formation litters the work area.

This domestic and ceremonial workshop has two sets of ovens as well as smaller ovens and pits in the ground. The latter serve for firing pots and other domestic ceramics and are thought to be analogous to workshops at Simbilá, near Piura and Catacaos (Christensen, 1955). The pit ovens are round to oval and are commonly 2–3 m in diameter, however, one pit was 7.8 m and another was approximately 5 m in diameter. Originally, the depth was approximately 1 m. The upper parts of several of the pit ovens had been reinforced with adobe that has since been calcined and gives the ovens a red color.

In the second area were two ovens, each 2 m high, and were interpreted as dual ovens for the preparation of more elegant ceramics. These ovens were oriented east-west and comprised 10 or so chambers that were 1.2 by 2.6 m in parallel rows and opened to an area that was 40 by 60 m. The ovens opened to the south, toward the sea, to take advantage of the afternoon wind that served as a bellows and heated the ovens to 900–1000 °C. The next step was firing and wood was put in the oven or pit. The air-dried ceramic was placed on top of the wood pile and then all was covered with broken pieces of ceramics, discards, and a thin layer of earth. The interior walls of the ovens were calcined and two zones were apparent: an upper zone that was bright red due to oxidation and a lower zone that was gray-black due to a reducing environment. Ceramics for domestic use were fired in the zone of oxidation as indicated by the brick red color and decorative ceramics were fired in the reducing zone as indicated by the darker colors.

Malachite and chrysocolla were the commonly used pigments. Pieces were found at the site and these were probably sourced from the copper mines near Ica. Wad manganese was used for dark-to-black stripes and patterns. In some ceramics, dark marks were seen that could have come from the use of manganese or iron oxides that would have darkened in the reducing zone. A small packet of this iron pigment was found at the Cahuachi site (Rio Nazca).

The ceramic fragments found on the surface belong to the early Paracas culture, Nazca, and Ica. Late Horizon is also possible as indicated by the ceramic assemblage at Toma Luz which was occupied from the Early Horizon to the Late Intermediate. A number of tombs that appear to be grouped by cultural epochs occur in areas with abundant ceramic production. The major parts of these have been destroyed by treasure seekers and clandestine excavations. In one example, the presumed tomb of a ceramicist was indicated by the presence of ceramics and smelter scoria from the ovens that identified the profession of the deceased. The ceramics found in this tomb were identified as belonging to the Middle Horizon (Epoch 3, Pinilla phase, approximately A.D. 1000).

The surface of the site had been altered and was covered by moving sand dunes which made it impossible to complete a detailed study without opening exploration trenches. Some utensils and tools such as granite polishers and a piece of an obsidian knife were also recovered from the surface. Outcrops of these types of rocks are not found locally, therefore, these materials must have been transported from distant sources. The most likely area is approximately 50 km distant. It is unlikely that these artifacts were made from river rocks because the nearby stream has only sand-sized material and no float of larger size.

The Toma Luz ceramic production site was evidently a regional fabrication center and was far from places where the material was used. Toma Luz ceramics have been recognized at archaeological sites at Ocucaje, Ica, Paracas, and others. The site served as a production site for possibly 2500 years.

Road Metal

The Spaniards and later travelers in the region commented eloquently on the well-constructed Inca roads in Ecuador. The foundation of the bridge at Cuenca has limestone mortar and bitumen (tar) and the Inca roads were paved in a similar style. Humboldt (1876), who traveled in Ecuador in 1802, said that parts of the road that were unsettled were filled with stone and with fine sand. Wolf (1892), who was accompanied by Dr. Reiss, also traveled in this region, mainly Prov. Azuagy, but saw no paved roads. In "Arte de Construir de los Antiguos Peruanos" Chalón (1882, p. 27) said that the gypsum of the ancient Peruvians was called *pachachi* and was used in various styles. The material was mixed with a type of bitumen, that was very common in various parts of Perú, and which resulted in a mortar that dried quickly and held the stones very well. Also, with the same mixture, they were able to prepare a very hard artificial stone. López de Gómara (1552) wrote that the building stones were seated with limestone and bitumen which could be seen in the anterior portions.

Adobe

Clay used for adobe manufacture contained a high proportion of sand in order to prevent cracking during the dry season. Straw, corn husks, and other vegetable materials were added during the preparation of the mud. The name in Quechua and Aymara, *tica*, *tika*. The primary material could be extracted from many places from the surface, especially in areas that were occasionally flooded, thereby leaving clay and sand grains of the appropriate size. In other cases, the material was obtained by mixing ingredients from different sources, without a specific recipe, and each adobe worker was guided by his own experience. Therefore, the quality of the adobe varied from site to site.

In Arabic, the name for adobe was *atob* or brick. Mud or mud-brick walls were made from clay and molded in boxes or in cane. In Quechua, *pirca*, *pirka*, *tica pirca*, *t'ura pirka*, a wall of clay/adobe. Another type of wall is called *quincha*, from Quechua, or *kencha*, and indicates a cane wall filled with mud or a dwelling made with walls of *quincha*.

Near Chincha, Lima, and to the north coast, earth walls, *tica pircca*, were used from pre-Inca time. In the mountains, these types of walls date to Inca time and this type of construction is still used.

Adobe was made manually, in molds, using forms or from cane that was roped together. The material used contained approximately 55% clay, 30% sand, minor carbonate, and other components including straw and manure. In its dried state, the material could support 2 kg per cm^2.

The type and size of the adobes varied by culture and region (Muelle, 1963). The following forms could be distinguished:

Conical (*cónica*)—style associated with the early coastal Chavin culture and made by hand. The Barbacoa and Puchuchi examples, from the Salamanca Hacienda, typically have a diameter at the base of 18–28 cm and a height of 27–40 cm (Larco Hoyle, 1941). Placement of the adobe is in the form of a rope. This style was described by Strong (1957, p. 15, figure 5e and 5f, p. 31) from the ruins of Cahuachi in the lower Nazca Valley and associated with polychromatic Nazca A ceramics (see Lumbreras, 1969 p. 192–208 and p. 200, Kawachi map).

Oval (*aovada*)—also made by hand, associated with the post-firing painted styles from Dept. Ica (Muelle, 1963, p. 327).

Spherical (*esferoide*)—this form is associated with the Baños de Boza culture (Muelle, 1963).

Paralapiped (*paralelepipedo*)—adobe made with a cane mold, from the Moche culture. When made by using a mold, it dates to the Chimú culture. The size of the adobes varies. At the ancient Tumbes fort, adobes are 50 cm in length, 25 cm wide, and 25 cm in height, and could be either Chimú or Inca. However, most Inca adobes are approximately 40–50 cm in length, 20–30 cm wide, and 10 cm in height. The Maranga ruins and other sites in the lower Rímac valley contain large constructions made of adobe bricks that are 12–15 cm in length.

Round top (*cabeza redondeada*)—adobes described as "round-top" by Kroeber.

Lenticular (*lenticular*)—at Virú, this style indicates an early period (Campana, 1939).

Spheroidal 2 (*esferoidal* 2)—a molded form that comprises two unequal sized blocks (Campana, 1939).

Spheroidal 3 (*esferoidal* 3)—ball shaped adobe.

Tooth-shaped (*odontiforme*)—cone or tricone shaped.

Coastal groups used adobe for construction material. However, there are also examples of walls constructed on foundations of natural stone, on adobe, directly on the surface, or on exceptionally large adobe blocks (*adobón*, see next section).

Small funeral towers or *chullpas* are another style of ancient adobe structure found in the valleys of the Altiplano near the Peruvian-Bolivian border. These were first described by Cieza de Leon during exploration in 1549 and are located in Sica-Sica, Patacamaya (along the road to Ayo), and Catamarca and were also seen in Oruru and Caracollo, Bolivia. These were also described by Hauthal (1911) and Ryden (1947). Trimborn (1959) provides a detailed study and says that these small towers are made of yellow-white adobe that contains straw and other materials. In other examples, the clay alternates with layers of grass at 5 cm intervals.

Adobón

This material consists of clay blocks, variable in size, with average dimensions of 1.5 m in length, 1.0 m in height, and 0.75–1.00 m in width. The primary construction material for *adobón* is clay, as it is for adobe. Because of the great weight of these blocks, they are constructed at the building site using a box mold of wood or strong cane. The blocks for the wall are placed upon a stone foundation and are seated with clay mortar. The *adobón* block is stamped during the casting in the mold and, after drying, is removed from the mold. The adobe walls of the Canchari Palace at Incahuasi, Lunahuaná Valley, have a height of no more than 4 m. After having dried, a slip of red clay is applied and the block may be given a final polish (Harth-Terré, 1933, p. 103). Walls constructed of adobe are rarely constructed vertically, and more commonly, are sloped or have the form of a truncated pyramid.

In the coastal regions of Perú are many ancient ruins that were constructed using techniques that necessarily required extraction of abundant primary material. To fully understand the enormous resources applied used for construction, consider the example of the Cajamarquilla ruins which are 20 km from Lima in the Rimac Valley, near the Nieveria Hacienda. The topography of the site is given on the aerial photomosaic from the Servicio Aerofotográfico Nacional (1:4,000 scale). Approximately 70 of the 75 ha of the site show ruins that include temples, patios, living areas, and other constructions. The original extent of the site was perhaps 25%–30% larger, however, much of the site has been covered or destroyed by debris flows (*huaycos*) resulting from torrential El Niño rains or from flooding and overflow from the Quebrada Jicamarca. With few exceptions, there have been sectors completely covered or removed by the effects of mud and floods.

At the site, there are outlines of three large buildings that cover an area of 25,000 m^2 and have a fill of 4 m. Dwellings were irregularly spaced. Murals at Cajamarquilla total some 94,000 m. Some of these are well preserved and are as high as 5–6 m; however, because of the partial destruction of the remaining walls and the fill produced by the fallen walls, it is difficult to estimate the original height. For the following calculations of volume of material, 4 m in height and 1 m in width is used:

~94,000 m of walls, 4 m in height and 1 m in width	376,000 m^3
Area of 3 buildings and fill, 25,000 m^2 and 4 m height	100,000 m^3
Volume of material	476,000 m^3
Weight of the material	904,000 mt
Weight of water	96,000 mt
Total	1,000,000 mt

This does not take into account the amount of material that was removed by *huaycos* and flooding.

Adobón construction was mainly used during the Late Horizon. The Cajamarquilla site gives an indication of the volume of material, as *adobón*, that was used by ancient people in the coastal areas. Extraction and preparation of clay, sand, and other materials would be estimated to be on the order of 30 million tons, a quantity of material that is comparable to the amounts used in the construction of modern buildings. The volume of material used at Huaca Esperanza, also known as Obispo, in the ancient Chimú capital of Chan Chan, near Trujillo was estimated to be 1,500,000 m^3 (Holstein, 1927). The weight of the material would have been 3,000,000 metric tons. There are also water engineering structures of great importance such as the aqueduct at Ascope, Dist. Trujillo, which was constructed A.D. 500–1000. More than 2,400,000 metric tons of material was used (Larco Hoyle, 1963).

Moving more than 55 million metric tons of construction material for public works is an impressive engineering feat that was accomplished during a time when there were no vehicles or work animals. This represents an extraordinary individual and community effort and gives a detailed idea of the ancient mining, extraction, and use of non-metallic resources.

CHAPTER 3

Metals

GOLD

In the mining of metallic resources, gold is the oldest because of the ease with which it can be found in many rivers and streams. However, archaeological evidence indicates its absence at pre-Ceramic sites. No worked gold, even as foils, has been found (Engel, 1958). Gold appeared in the archaeological record in Perú 800–1000 B.C. during Chavin time and its use grew markedly during the Moche, Chimú, and into Inca time. The name in Quechua, *kori*, *cori*, (Sto. Tomás, 1560); *ccori* (González Holguín, 1608); *kori'hina champi*, *oropel*, gold flakes (Middendorf, 1890); *kori chajra* or *cori chacra*, gold mine. In Aymara, *choke*, *chocque*, *chuqqe*, *qori* (Torres Rubio, 1616). Gold was also poetically referred to as "Tears of the Sun."

Colombia

Although Colombia was not a part of the Inca realm, the details of ancient gold mining justify discussion. Since the discovery of the Americas in 1492, news of fabulous gold riches was widespread and one of the more well-known documents was "Historia de las Indias" by Gonzalo Fernandez de Oveido (1526; republished 1950, p. 247). This report, written after the Conquest of Perú, gives a description of gold mining at the Castilla del Oro. Fernández de Oveido served in the New World for 12 years as an observer at the mines and of gold processing. He described mining laws at Castilla del Oro that were different than in ancient Perú. During Inca time in Perú, there was a state monopoly on gold mining, however in Colombia the mines were privately held. Each miner could make a claim and thereby obtain gold just like larger organizations that produced the gold using slave labor. There existed free trade of gold and gold products (Trimborn, 1948).

Fernández de Oveido found that the purity of Colombian gold was commonly 22 carats. The largest gold nugget that he saw in this part of the New World was approximately 3,200 castellanos or 14 kg. These ancient gold production methods were also described and confirmed by Cieza de León (1553–1924, p. 55, ch. XIV) after having visited Buriticá and Antioquia. According to Fernández de Oviedo, gold was mined by opening pits or shafts that were about 1 m in diameter and up to 25 m deep and could only accommodate one miner at a time. It is not known if galleries were cut, however the shafts were cut from one side to the other. Gold was taken also in the plains (*llanos*) or from rivers by using shallow pits and shafts. The gold-bearing gravel was washed in the river by a well-organized workforce composed of thousands of miners and other workers. The gold regions described by Fernández de Oviedo are near Buriticá, to the north of Antioquia. At this site, ovens, molds, and other items used for metal production were found (Trimborn, 1948).

Perú

Gold occurrences in Perú are found all along the Andean cordillera and also along the eastern and western slopes. These occurrences are in veins and alluvial deposits. Extraction methods are technologically unique for each type of occurrence and the method used for final concentration of the gold was similar for both types of gold deposits.

Gold mining, strictly speaking, was usually a small undertaking that slowly grew and reached a peak during Inca time. It is very difficult to estimate the number of pre-Columbian gold mines mainly because Colonial mining has erased traces of the ancient workings. With all the information at hand, it is worthwhile to consider this type of mining which resulted in a large tonnage of gold.

Vein Occurrences

Native gold is found in quartz veins, with or without pyrite or other minerals. Name in Quechua, *quijo* or gold-bearing quartz. Gold-bearing veins containing arsenopyrite and tellurides were rarely accessible to the ancient miner and typically were not used. Gold was preferentially found in the oxidized zone associated with the gold and silver veins.

Some mines can easily be classified as pre-Colonial because ancient tools and other artifacts of ancient Peruvians were found inside; others are known to be pre-Colonial based on the Colonial chronicles; and travelers and explorers also added information from their trips. Ancient hard-rock gold mines were almost always at high altitude where the veins had been exposed by Pleistocene glaciation and erosion. The explorer W. Pentland, in a letter to Alexander von Humboldt, describes sedimentary rocks near snow-covered mountains that are Paleozoic slates cut by quartz veins. The quartz veins contain gold-bearing pyrite as well as native gold. Because of the altitude, approximately 5100 m, the occurrences had been mined by the ancient Peruvians well before the arrival of the Spaniards (Humboldt, 1829, p. 15). Pentland refers to Cerro Descuelga, in particular, on the north slope of Illimani, where there are gold-bearing quartz breccias at more than 5000 m. Even though the slopes here are very steep, many adits and mines, where the ancient miners worked the gold-bearing quartz veins, can be seen.

At Nevado Ananea, northeast of Poto (Puno), between 4900 and 5100 m, are a number of adits and ancient dwellings that Molina (1891) dates to pre-Colonial time. However, no evidence has been found that confirms Molina's interpretation. Aguilar Condemarin (1938) and others note that glaciers at Ananea were in retreat, thereby exposing ancient workings. At La Rinconada del Ananea, the quartz veins are exposed under the glacial ice.[6]

Among the locations where gold-bearing quartz veins were worked by ancient miners, Aguilar Revoredo (1940) lists Apurímac, Cotabamba, Colquimarca (Cajamarca), Ica, Nazca, Patáz, and Paucartambo. Olaechea (1887, 1901, p. 9) includes Challhuanca and Ayamaya as having been worked during Inca time.

Posnansky (1945/1957) interprets the process of amalgamation as having been used before arrival of the Spaniards. In Perú and Bolivia are large sites with indications of ancient gold production. For example, at Hoabamba (Nusta Hispana), downriver from Machu Picchu, there is a workshop cut into the rock and there is also a very old mill for processing gold directly from the outcrop. Also near Machu Picchu, there are crushing and amalgamation mills that were used to treat the gold-bearing quartz. In this region, as in diverse regions of Bolivia, are places called *Kjory-Huayra-China* and *Kollke Huayra-China* which translates from the ancient Khollas language as "wind furnaces for smelting gold and silver." The ancient people smelted their metals at night and their furnaces were called *huayrachinas*. Night winds as well as animal-skin bellows were used to raise the temperature of the furnaces. Posansky's plate CIX has a legend that shows a gold processing mill and an Inca outpost, at Hoabamba, near Huayna Picchu (Perú, Rio Willcanota).

Alluvial Occurrences

In northern Perú, the gold from the Rio Chinchipe is 750/000 fineness (Casa de Moneda, oral commun, 1970). Panizo (1934/1935) explored this region and found very fine-grained gold that was 810/1000 fineness or 19–20 carats in horizontally extensive alluvial deposits of variable thickness. Samples taken at Huaquillas, Surunde, and Perico gave 0.112–3.10 g/ton^3 with an average of 0.864 g/ton^3. Other valleys where alluvial gold was mined by ancient Peruvians includes the Rio Mariñón, Rio Santiago de la Montaña, Rio Aguarrica, Rio Morona, and Rio Chachapoyas (Aguilar Revoredo, 1940). The alluvial gold in the Rio Ucayali is generally 750/000 and the rest is silver (Casa de Moneda, Lima, oral commun., Ing. J. Becerra, 1970). See discussion on occurrence of native platinum in the Rio Santiago alluvial gold occurrences.

In northwestern Perú, the number of vein-gold deposits in the coastal area is small. The few alluvial occurrences are mainly associated with the Rio Tumbes, Rio Calvas, Rio Santa, Rio Chuquicara, and Rio Ocoña drainages. Some are near Arequipa. None of these occurrences are of economic importance with the exception of the Rio Tumbes, where gold has been mined since before A.D. 400. In the valley of the Rio Tumbes there are two zones with concentrations of native gold. These include Ricaplaya, in the extreme lower part of the Estrecho del Mango and Puyango, located along the middle part of the Rio Tumbes. In this section, the gold-bearing sands have an irregular thickness of 0.1–2.0 m and are above Cretaceous lutites (Petersen, 1964, photo p. 13). The gold in the Rio Tumbes originated in the gold district of Zaruma (Rios Amarillo y Galera) in Ecuador. The gold concentrate contains magnetite, tourmaline, and garnets, locally called *gallirpa*. The output from small-scale mining, using *bateas*, is typically 2–9 g per man per day.

Alluvial gold from the workings along the Rio Tumbes is light-yellow to almost white. The chemical composition of the gold from the Zaruma alluvial sands is from Wolf (1892, p. 318):

Au	72.93%
Ag	26.74%
Cu, other	0.73%
	100.00%

The gold from the Rio Tumbes is approximately 17.5 carats and the gold from the veins in the region is commonly 15–19 carats or a fineness of 624–748/000 (Wolf, 1892). The high proportion of silver in the native gold from northern Perú characterizes a geochemical trend that continues into Ecuador and Colombia (Table 5). Electrum (from Greek, literally meaning white gold) is typically 75% gold or 18 carats; this term has been used since approximately 700 B.C. and was used to describe gold from the Pactolus River (Turkey) and other rivers in Asia Minor where gold for ancient coins was mined.

In southeastern Perú, the alluvial deposits contain gold as powder, flakes, and nuggets that are a centimeter or more in size. Large nuggets are frequently found in the sands of the Rio Sandia, Rio Tambopata, and Rio San Gabán. In the Museo Oro del Perú, a nugget that weighs 1950 g is on display (no. V, 58-4846). This nugget came from Mina Candelaria, located 40 km northeast of Macusani, in the Rio Macumayo, a tributary of Rio Caxiles that runs into Rio Ayapata, a tributary of Rio Inambari.

The gold is smooth and has a Brinell hardness of 50. The surface has been smoothed by alluvial transport from its source. Alloys with other metals such as silver or copper tend to have an increased hardness (Table 14).

There are few published data on the fineness of gold found in alluvial and glaciofluvial occurrences in Perú. In general, gold data refers to the amount of gold in a cubic meter of material. However, in Prov. Carabaya and Prov. Sandia, the gold is 20–22 carats or 833–916/000 fineness. Similar values have been found in gold from veins that cut the Ordovician slates at Nevado Ananea (Molina, 1891). Cieza de León (1533) indicates that vein gold from Carabaya is 23–24 carats. It is unlikely that the Colonial writers determined any gold values and probably obtained some data from the mines and smelters. The purity of the gold was likely determined by comparison with a jewelers touchstone or streak plate (siliceous slate or hornfels was used and the touchstone was also known as Lydia's rock or simply lidite). This method only permitted an approximation at intervals of 8, 10, 12, 14, 18, and 20 carats. Better determinations could be made using a set of specialized needles or blades marked from one to 24 carats (also see Agricola, 1548, 1950 edition, p. 255).

A study of the composition of alluvial gold in the Sandia region was undertaken and analyses were obtained courtesy of the Laboratorio Espectrográfico, Corporación Cerro de Pasco, La Oroya. The samples were obtained at sites visited in 1933–1934 and another sample, from Poto, was provided by Ing. José Peña Prado. Site descriptions are given below:

1. Anccocala—Alluvial deposit from glacial morrain, 16 km north-northwest of Poto and 15 km northwest of the gold-bearing veins of San Francisco at Nevado Minacuyo, at the extreme western part of Nevado Ananea (Fig. 3). The gold has been pulverized by glacial action to particles that are 0.2–0.3 mm in diameter. In addition, there are thin flakes of gold up to 2 mm in diameter. (CP)
2. Vetasmayo—Tributary of the Rio Tambopata, approximately 60 km north of Poto. Angular gold grains without any evidence of rounding or transport by streams were obtained using a *batea*, a traditional artisanal gold pan made of wood, and by washing detrital sand near an adit that likely dates to Colonial time. (CP)
3. Chinihuaya—Gold-bearing sands at the confluence of the Rio Inahuaya with Rio Saquí, upper part of the Rio Tambopata. Gold flakes are 0.1–2 mm in diameter and there are occasional flakes that are up to 3 mm in diameter. (CP)
4. Llamillami—Tributary of the Rio Tambopata, from gold-bearing sands approximately 10 km downstream from Chinihuaya. The gold occurs in small flakes that are very thin and may be up to 6 mm in diameter. (CP)
5. Chabuca—At an elevation of approximately 1500 m, 5 km west of Mina Santo Domingo, (Inambari), gold occurs as very thin flakes up to 4 mm in diameter. (CP)
6. Sandia—At an elevation of approximately 1500 m, gold is found in alluvial sands in the streambed, as nuggets up to 2 cm and 4 mm thick. The gold-working area is approximately 10 km downstream from the village of Sandia. (CP)
7. Poto—Gold is associated with moraines and fluvioglacial deposits at an altitude of 4750 m and approximately 10 km southwest of Nevado Ananea. This deposit has been worked since ancient time until present day. The gold flakes are fine-grained and are 0.1–0.2 mm in diameter; however, some may be as large as 5 mm. (CP)

For the study, spectrographic analysis was used to determine 48 elements, and 22 elements characterized the gold content of the samples indicating common regional geochemical attributes (Table 2). Supplemental analyses for gold and silver from six of the samples were done by the Inorganic Chemistry Laboratory of the Universidad Nacional de Ingenería in Lima (Cert. no. 25873, 31 December 1970). The results of this analytical work have been incorporated in Table 3 under data from Carabaya and Sandia. The two types of analyses, though different, show significant details for gold samples obtained in a relatively small region. The gold grade is high and oftentimes higher than indicated in other studies. There is a large variation between the different sites. The

TABLE 2. SPECTROGRAPHIC ANALYSES OF NATIVE GOLD FROM THE SANDIA REGION, PERU

	Anccocala	Vetasmayo	Chinihuaya	Llamillami	Chabuca	Sandia	Poto
Ag	M	M	M	m	M	M	M
Al	V	–	V	V	V	V	V
As	–	–	–	–	–	W	V
Au	M	M	M	M	M	M	M
B	–	–	–	–	–	V	–
Bi	V	V	V	–	V	V	V
Cd	V	–	V	–	V	–	–
Co	–	–	–	–	–	V	–
Cr	–	V	–	V	V	V	V
Cu	S	W	W	S	S	S	S
Fe	S	S	S	m	S	S	m
Hg	S	–	S	–	S	S	S
Mn	W	–	V	–	V	–	V
Na	V	–	V	–	V	V	–
Ni	–	–	–	–	–	V	–
Pb	V	V	V	V	V	V	V
Sb	V	V	V	–	V	–	V
Si	S	V	W	V	V	S	S
Sn	–	V	S	–	W	V	m
Ti	–	–	–	–	–	V	W
W	W	–	W	–	–	–	S
Zn	–	–	–	–	–	V	V

Note: Analyzed for: 48 elements. Detected: 22 elements
Key: M = >10%; m = 1.0–10%; S = 0.1–1.0%; W = 0.01–0.1%; V = < 0.01%.
Lab. Espectr. Oroya, Cerro de Pasco
Inf. 405:16-XII-665-666-70, J. Cueva
Inf. 438:08-XII-331-333-70, E. Manrique
Inf. 439:08-XII-334-335-70, E. Manrique
Inf. 442:14-XII-531-70, E. Manrique

TABLE 3. CHEMICAL ANALYSES OF NATIVE GOLD FROM PERU AND ECUADOR

	Au%	Ag%	Cu%	Fe%	Reference
ECUADOR					
Zaruma (headwaters of Rio Tumbes)	72.95	26.34	0.73	–	Wolf (1892, p. 318)
PERU					
Northern Perú/Chinchipe	81.0	–	–	–	Panizo (1934/1935)
Ucayali	75.0				Casa de Moneda (Lima)
Ancash					
Ninamahua	89.2	4.8	6.5	–	Raimondi (1887)
Pallasca	84.3	8.4	7.6	–	Raimondi (1887)
Carabaya					
Chabuca	98.3	1.7	–	–	(CP) Lab. An. Qu. Inorg., UNI
Challuma (Inambari)	97.3	2.4	0.03	0.05	Raimondi (1887)
Ccapac-Orcco	97.1	1.8	0.04	0.8	Raimondi (1887)
Quimsamayo	96.5	2.5	0.04	0.3	Raimondi (1887)
Quincemil	96.0	–	–	–	Casa de Moneda (Lima)
Marcapata	95.5	–	–	–	Casa de Moneda (Lima)
Sandia					
Sandia	98.5	–	–	–	Casa de Moneda (Lima)
Llamillami (Tambopata)	98.2	1.9	–	–	(CP) Lab. An. Qu. Inorg., UNI
Poto	94.4	5.6	–	–	(CP) Lab. An. Qu. Inorg., UNI
Sandia	91.6	8.4	–	–	(CP) Lab. An. Qu. Inorg., UNI
Vetasmayo	85.2	14.8	–	–	(CP) Lab. An. Qu. Inorg., UNI

high silver content in gold from Vetasmayo is explained by its sourcing from a vein occurrence that is different from occurrences in the valley. The presence of tin and tungsten are interpreted to reflect general regional mineralization (Petersen, 1965; plates 16 and 17).

For comparisons with other gold regions as well as with gold artifacts produced by ancient craftsman, the major elements such as Ag, Cu, and Fe are important as well as other elements such as As, Cr, Hg, Sb, Sn, and W. The absence of Pt and other platinum group metals that are in the Andean cordillera are also important in such studies.

Alluvial Gold Mining

Ancient mining of alluvial gold deposits was mainly by small, shallow diggings or adits when practical. The material was then taken to a source of running water where the gold was gravity-concentrated using a *batea*. Alternatively, gold-bearing alluvial material was sprayed with water from jets (hydraulic mining), or monitors, so that the material would collapse into a man-made canal or sluice for concentration of the gold. This was a common practice at Pampa Blanca at the foot of Nevado Ananea (Fig. 5). In the canal, or sluice, were riffles of medium-sized gravels that permitted the gold to concentrate in the interstitial spaces between the gravels. The stone riffles could be 50–100 m long, depending on local conditions, and were then cleaned so that the gold could be further concentrated in *bateas*. After the material had dried, the gold was separated from the other heavy minerals by blowing or by wind action similar to the way grain is separated from chaff. This gave rise to the term *aventadero* for using wind to separate the heavier gold from the lighter material.[7]

The placer gold deposits in Carabaya and Sandia have been mined since ancient times and can be divided into three groups:

1. Moraine and glaciofluvial placers—includes extensive alluvial gold deposits in the plains near Poto, Anccocala, and others and also in the foothills of the hills composed of glacial moraine.
2. Alluvial terrace placers—includes alluvial gold deposits in the western slopes of the Andes that may extend for a few meters up to 200 m and may be 10–50 m thick. These types of placers may be found near Aporoma, Cachicachi, Chunchusmayo, San Juan, Iparo, Llenqueni, and other sites.
3. Placers at or in present-day rivers and streams.

The alluvial sands and gravels at Valle Tambopato have a thickness of 10–20 m and are composed of several gold-bearing strata. The most significant concentration of gold is found in the basal conglomerate that overlies Ordovician slates (Fig. 4). An adit cut at the base of the gravels contained 10–15 g per m^3 and was the chief exploration target. Alluvial terraces nearby generally contained 0.5–1.5 g of gold per m^3 (Petersen, 1932, p. 60 and plate 1).

The water needed for placer gold processing commonly came from a nearby stream or directly from glacial outwash streams. To regulate the water flow, the water was dammed or held in small tanks. Name in Quechua, *cocha*, tank; *tojllay*, catch in a sluice or trap, in this case with stone riffles (Middendorf, 1890); *tokklla* (Lira, 1945); *toqlla*, *toclla*, rope used for hunting (Perroud and Chouvenc, 1970); *chichiquiar*, to wash alluvial material for gold using a *batea*, possibly related to *chihchi*, ice-grains and *ch'ichi*, to be small; *ch'ichi kkori*, gold dust (Lira, 1945); *ccorihuayrachapata* and *korihuayrachina*, place where gold is winnowed by air (Olaechea, 1887, 1901).[8]

Bolivia

Ancient miners knew about gold occurrences near Nevado Illimani as well as other gold occurrences near Oruru and La Paz. Ahlfeld and Schneider-Scherbina (1964) list ancient gold workings at Tacacoma, Yani, and Aucapata. As a historical note, the city of La Paz was founded at an ancient mining site originally known as Choquiyapu, from Aymara, *choqque*, gold, and *yapu*, gold/mineral property. This root is also found in Rio Choqueyapu, Chuquiapu or Chuquiabo, which is the ancient name for the river that runs through La Paz that is now simply called Rio La Paz. Cieza de León, in describing his travels to La Paz in 1549 says that "…to arrive at the city of La Paz, leave the Inca road and go towards the town of Laxa, from which you will arrive at La Paz after passing through a steep, but small valley that is surrounded by hills and this is where the city was founded. La Paz was founded in the valley of Chuquiabo where there was abundant gold and many rich miners. The Incas had an exceptional resource at Chuquiabo."

Alonso Barba (1640, p. 45) also confirmed that La Paz was a gold district and said that the correct name for La Paz was *Choquiyapu* which had been corrupted to *Chuquiabo* which translates in the regional language to a "gold field." There were many workings in the area during Inca time. The area was especially rich in this metal and during floods, gold nuggets could be found in the streets, especially those that were below the Predicadores Convent. And in the Coroico Valley and other areas that drained the Andes near Chuquiabo, gold was found in many streams, however, the gold was dark on the surface, and looked like lead.

Production of alluvial gold also took place before the arrival of the Spaniards, and Posnansky (1957, p. 164) found that there was a large and active gold industry in Alto Perú (Bolivia). Near Vilaque, not very far from the site of Tiahuanaco, were signs of large pre-Columbian alluvial gold processing areas. Since very ancient times the gold had been washed from the streams in the area. However, by the time that the Spaniards arrived, only the waste rock remained. The same could be seen in Chungamayo, in the Yungas region of Bolivia and downstream from La Paz, and in Chuguaguillo, near La Paz.

SILVER

Ancient Peruvians also prized silver, which also had a role similar to gold, in religious and other ceremonies. More than in any country in South America, silver was found as a native metal or in simple or complex ores. The name in Quechua, *ccollcce*, *collqui*, or *colqui*; *kollke aca*, silver slag from *kollke* meaning silver and *aca* meaning waste or a product of oxidation; *yuraj kollke*, refined silver, from *yuraj*, white to transparent. Type area, Colquijirca, silver vein, from *jirca*, vein; in Aymara, *qollqe*, plata; en Yunga, *xllaxll* (Carrera, undated); *jai* or *jaij* (Middendorf, 1890); *jiay* (Villarreal, undated); *jiai* (Larco Hoyle, 1963); *quellay* (Carranza, 1922); *hil'a*, in Chinchaysuyo dialect, from *kila*, from *killay* meaning fineness.

In Quechua, several words may be used that relate to silver and silver mining such as *llampos*, when the vein is smooth, from *llampu*, meaning smooth:

Vilaciques, reddish silver, with sulfur, antimony, or arsenic (Alonso Barba, 1640).
Pacco, *ppaco*, tin oxide and reddish to yellow silver, also silver mineral with trace iron.
Llipta, describes ore with chlorargyrite (AgCl).
Cique, waste rock taken from the mine along with some minerals (Alonso Barba, 1640, p. 292)
Callana, clay fragments, crucible.

Production of native silver and lead-silver ore in ancient times required little more than manual labor because the ores were commonly found in altered zones called "iron hat." These were brightly colored areas that might be yellow to red. The color was caused by the reaction of meteoric water on the sulfides associated with the silver veins. Sulfuric acid was produced by this reaction and the iron was released, was then oxidized, and formed the rust-colored "iron hat." This class of secondary mineralization is common in the Andes, specifically at Hualgayoc, Micuipampa, Yauricocha, Cerro de Pasco and many other places. Samples with iron oxide and native silver, both microscopic, and in veinlets are in many museum collections. Klaproth (1804) analyzed a sample of *pacco* from Dist. Yauricocha, now known as Cerro de Pasco:

Ag	14%
Fe-ox	71%
SiO_2	3.5%
Other	9.5%
	98%

The extraction of silver ore was relatively easy for the ancient Peruvian miner. Pedro Pizarro (1571, 1968, p. 488) wrote that Don Francisco Pizarro, while in Prov. Cajamarca, noted that there was a range which was burned and after the fires had died down, native silver was easily found. The exceptional silver riches found in numerous places, even after exploration and mining by ancient Peruvians as well as the Spaniards, was described by A. von Humboldt (1849, 1876, p. 557–559) in the mining district of Chota in the hills of Cajamarca "The hill of Gualgayoc is composed of silicic rock cut by an infinite number of veins…this silver mountain of Gualgayoc is cut by many adits…near Mucuipampa is a high plain called Llanos or Pampas de Navar and there is an extension of the hill with enormous amounts of red silver with antimony as well as native silver all just below the surface… and, after having traversed the hills of Choropampa, and also at the surface, is a rich gold deposit, with a fringe of silver veins… nature has generously offered exceptional mineral wealth to the ancient miner."

The number of silver mines that have been worked from 200 B.C. until the end of the Inca period is immense. Information on pre-Columbian mining is found in Cieza de León (1533), Alonso Barba (1640), Francisco de Jeréz (1534), Carranza (1922; 1940), Polo (1911), Jiménez (1924), Aguilar Revoredo (1940), Bargalló (1955), Schnapka (1962), and Solari (1967). The regions included in these studies are: Ancash, Cajamarca, Caylloma, Cerro Lin (Micuipampa), Cusco, Charcas, Chincha, Guanesa (Huánuco Viejo), Huamanga, Huaráz, Huantajaya, Oruru (Cerro de la Plata), Porco, Taparacá, and Yulloma. The National Archives contain numerous documents in which native Peruvians make claims for mining rights and mines that date to the Inca period.

The abundance of silver that was in Porco and Potosí (Bolivia) was described by Cieza de Leon (1553/1924, p. 306): "It appears from what I have heard, that in the time when the great Inca kings ruled ancient Perú, a great quantity of silver from Prov. Charcas was taken and given to the Spaniards. And, at Porco, which is near Villa de Plata (Chuquisaca), are mines from which silver was taken for the Spaniards; and it is known that much of the silver that was in the Temple of the Sun at Coricancha was taken from Porco."

In ancient times there were three principal regions of silver riches: North America, Central America, and the central Andes. Silver has been known in Perú since 100 B.C.; in the Altiplano of Perú and Bolivia since A.D. 600; and in Ecuador since A.D. 500–600. Silverworking reached its heights in Perú from A.D. 1000–1470. An exceptional silver mask from the Tiahuanaco period was found at Pachacamac (Muelle, 1965).

As an example of the quantity of native silver that dates to pre-Columbian and Colonial time, the narrative of Helmer (1962, p. 297) is useful, "Because of the civil war, from 1545 to 1550, the Potosí ores produced more than a ton of silver daily and surpassed the treasures of silver of Atahualpa and the metal producers in Cusco. The average annual production of silver during Colonial time was estimated to be 200 tons annually which corresponded to 68% of world silver production. Production of these ores was relatively easy until 1566. After this time, the amount of native silver began to decline leaving only polymetallic ores that neither the Spaniards nor the ancient miners knew how to smelt."

The relatively easy-to-find deposits of native silver that had been mined in ancient times had come to an end. The ore samples present in collections in geology museums may not be representative of the deposits. Many samples were sent to the Royal Mineralogical Museum in Berlin and 250 samples were offered for sale in Europe (Helms, 1798, p. 270). Included were a dozen or so samples of native silver from Colguijirca (Cerro de Pasco), Chanca, Huamanga, and Huantajaya; galena and silver-bearing arsenides, and many other samples could have been used for chemical studies of ores used by ancient Peruvians.

A sample of native silver from Mina Andaychagua at San Cristobal, to the south of Yauli, was analyzed by the Laboratorio Espectrográfico, Corporación Cerro de Pasco, La Oroya, and gave the following results:

Ag	M
Al	V
As	V
Ca	V
Cu	V
Fe	S
Hg	V
Mn	W
Pb	V
Si	V
Zn	V

Note: Analyzed for 48 elements, 11 detected. Key: M = >10%; m = 1.0–10%; S = 0.1–1.0%; W = 0.01–0.1%; V = <0.01%. (Report 666, 16/12/1970 by J. Cuevas).

The composition of native silver is relatively simple compared with the composition of native gold which may have double the number of elements. Because this silver sample comes from a lower level of the underground mine, it is not easily comparable to the composition of native silver from outcrops that were worked by the ancient miners. This analysis serves to indicate the need for more research and analysis of the silver used for ancient artifacts.

COPPER

Metallic copper is usually reddish with a hardness of 3. In ancient Perú, copper use dates to the early horizon (Cupisnique culture of Larco) at approximately 600 B.C. The abundance of copper artifacts for domestic use, farming, weapons, and copperworking all indicate a great demand for copper. The lack of studies and statistics make it difficult to estimate the tons and volume of copper consumed during pre-Columbian time. It is similarly difficult to estimate the extent of copper mining that took place in ancient Perú, however, copper was used widely and was very important to ancient Peruvians.

The name in Quechua, *ante* or *anta* is used for red-yellow metal in general; *pucca anta*, red metal; *anta*, pure copper; *anta rumi*, copper ore; *anta kaka*, copper vein; *anta chaj'ra*, copper mine. Type area: Anta, Antabamba, Antamina. In Aymara, *yauri*, copper. Type area: Yauricocha. In Quechua, *cocha* or *ccocha*, lagoon. In Aymara, *ccota* or *quota*, lagoon.

Generally speaking, the ancient Peruvians who lived in and near the Andean cordillera regularly used native copper. However, because of geochemical reasons, native copper was only rarely found in outcrop. Copper deposits, in outcrop, may form from meteoric waters acting on copper-bearing minerals and yield secondary copper minerals that can be easily identified by their green (malachite) and blue (chrysocolla) color. To form native copper, the meteoric waters must move below the zone of oxidation to a level free of CO_2, where reactions with primary copper and iron minerals form native copper, as well as secondary minerals such as oxides (cuprite), and zones of enrichment. The ancient miner rarely had access to the deeper zones. Only in a few sites where erosion had removed some of the overburden was it possible to find native copper, though generally in small quantities. This was commonly the case of the many outcrops of disseminated copper sulfides in the region.

Modern mining has preferentially mined the enriched zones and has exposed exceptional examples of native copper. In the Museo de Geología, Universidad Nacional de Ingenería (Lima) is a copper sample that came from the enriched zone of the copper-silver deposit of Cerro de Pasco. Its dimensions were 0.95 m by 0.55 m by 2 mm and it weighed approximately 2.9 kg (Fig. 6). Other mines where native copper has been extracted include: Cobriza, Yauricocha; Yauyos; Raúl (Mala), Cruz del Pilar, Canza (Ica); Chclocochа; Castrovirreyna (reticular); Huancavelica (rose-shaped); Paucartambo, Cusco; Sacsaquero y Yanacancha, Cerro de Pasco. There are references in Raimondi (1939, sample 1560) to dendritic native copper, as a small flat piece of native copper in a dendritic pattern formed by the intersection of many imperfect crystals, from a mine a short distance from the town of Ocuviri (Dist. de Ocuviri, Lampa). Sample 1561 is another flat piece of copper that is 35 cm long and a few millimeters thick that is also in a dendritic pattern and comes from the same mine.

In North America, the use of copper dates to 3000 B.C. and copper was widely used from Alaska, to the Atlantic, and in the southwestern United States. This is the only case in the world of copper use preceding the use of ceramics (Alcina Franch, 1970). In Perú, copper use dates to approximately 600 B.C., and in Bolivia from A.D. 800–1200. A copper necklace was found at Cerro Colorado (Paracas) in the tomb from the Cavernas culture (700 B.C.) (Muelle, 1965, p. 5).

MERCURY

Native mercury is typically found as tiny droplets on the outcrop. Occasionally a geode may be found that is full of mercury. Mercury is silver- to tin-colored, shiny, and liquid at normal temperatures and has a specific gravity of 13.59. Cinnabar (HgS), the sulfide of mercury, is scarlet red and is the only important ore of mercury. In Quechua, *llimpi*, *paria*, or *pari* and other names are given in the previous section on cinnabar.

Localities include: Chachapoyas (Amazonas); Santa Apolonia (Cajamarca); Buldibuyo (La Libertad); Huacrachuco, Paccha, and Chonta (Huánuco); Santa Cruz, Huaráz, and Santa (Ancash); Punabamba, Pucoray, and Yauli (Junín); Quipán (Pasco); Pariamina, Huarochirí (Lima); Cerro Chayllatacana, Villa Rica de Oropesa, (Huancavelica); Chuschi (Ayacucho); Ayaviri and Azoguine (Puno) (Cabrera La Rosa, 1954).

Before the arrival of the Spaniards, native mercury was obtained in small amounts from occurrences in sand in drainages within the Huancavelica region and possibly from processing cinnabar. Bargalló (1969) indicates that native mercury was known in ancient Mexico as indicated by the presence of several ounces of mercury in a tomb at Copán (Honduras). Cinnabar was commonly used as a pigment.

There are contradictory versions concerning the ancient use of mercury and cinnabar. Antze (1930/1965) suggests that mercury was used to gild silver or gold to other artifacts, however, the major use of cinnabar was evidently as a pigment which was used to decorate pottery or to paint the walls of temples (Muelle and Wells, 1939).

According to Garcilaso de la Vega (1609), the toxic properties of mercury were well known. It was dangerous to those who mined and processed cinnabar; it caused shaking, loss of senses, and death. These data suggest that mercury was retorted from cinnabar and the workers were exposed to the toxic mercury fumes. Mercury retorts that date to A.D. 1400 were found near the city of Huancavelica (Rivero and Tschudi, 1851).

ADDITIONAL OBSERVATIONS

Tin

This silvery metal has been known in Asia for more than 5000 years as a component of bronze in Mesopotamia as early as 3500–3200 B.C. With the rare exception of the tin placers of Australia, tin is not found in native form and is found instead, as cassiterite or is formed as sulfosalts by metallurgical processes. In ancient Perú, tin-bearing copper ore was used; however, the tin was a minor component. A tin belt was found as part of an Egyptian funeral assemblage on a mummy that dated to approximately 600 B.C.

In the ancient world, tin was widely used and had many names: in Sanscrit, *kastira*; in Arabic, *kasdir*; in Greek, *kassiteros*; in Latin (during Pliny's time), *stannum*, which originally referred to an alloy of lead and silver. However, during post-Classic time, there was also *plumbum nigrum*, lead and *plumbum candidum* or *album* which was equivalent to the Greek word, *kassiteros*.

In Quechua, *titi* or *tite* (Santo Tomás, 1560); *chayanta* or *yurac titi* (González Holguín, 1608), (from *yurac* or *yuraj*, white and *titi*, lead; to differentiate from *yanac titi*, meaning lead, from *yana* or *yanac*, meaning black, González Holguín, 1608) *chayanta*, *yuraj titi* (Middendorf, 1890); *chayanta*, *chapi* (Lira, 1945); *chayanta*, *yurac titi* (Perroud and Chouvenc, 1970). Tin in Aymara, *causi* or *kausi*, *titi* (Torres Rubio, 1616; Wiener, 1880). The origin of the word is from Prov. Chayanta, Bolivia.

It is an educated guess that the words *yanac titi* (lead) and *yurac titi* (tin) were Quechua words during pre-Columbian time. It seems likely that the European priests, who knew Latin, tried to establish a lexicon analogous to Latin usage.

Bolivia

Ahlfeld and Muñoz Reyes (1955) described deposits in the Bolivian tin belt from the border of Perú to the north of Argentina. The ores contained an elevated amount of iron, sulfur, and SiO_2 as well as trace amounts of arsenic, antimony, copper, lead, and bismuth. Cassiterite usually had iron, aluminum, and silicon. Stannite was also found in a variety of mines along with antimony. Near Escoma, alluvial tin was found along the banks of Bolivia's Lake Titicaca.

Alonso Barba (1640, p. 54) discussed tin mines that were worked in pre-Columbian time. At Carabuco, one of the villages along the banks of Lago Chucuito and along to Prov. Larecaja, are tin prospects that were worked by the Incas. The veins are rich and also contain silver and some copper, which makes a very hard and shiny metal. There are other occurrences of tin, but these are not well known and they do not contain silver.

Romaña (1908), who also explored the Bolivian tin deposits, did not find the ancient workings because these had probably been destroyed by modern exploration and mining. The veins described correspond to the oxidation zone where the cassiterite is very fine-grained and where pyrite also occurs. When describing the majority of the copper utensils and tools found in the region, there is little tin. Romaña (1908) is of the opinion that bronze is the result of copper ores with variable tin content rather than intentional alloying of copper and tin.

Chile

Solari (1967, p. 52) indicates that silver, gold, and copper were used in Chile and were alloyed with tin, which had been obtained through trade with the inhabitants of the Bolivian Altiplano.

Perú

The first use of tin in Perú is not known, however, it might have been used as early as the middle of the first millennium. There is archaeological evidence that tin was used during Inca time. At Machu Picchu, Bingham (1930) found a rolled tin belt that was 99.79% tin and 0.08% antimony, supporting the idea that tin was intentionally used in the manufacture of bronze. Lothrop (1953, p. 88) wrote that Cortez found abundant tin discs from Taxco, Mexico; he used these as a resource to form bronze for making canons. Harvard University's Peabody Museum has a disc of tin obtained from excavations at Chichen Itza, Mexico.

Metallurgy in southern Perú, from the Inca time, indicates considerable use of tin. This is based on descriptions from Cusco when it was taken in 1533 which were described later in the chronicles of Battista Ramusio (1545). Many different colors were used for painting cloths and these colors were obtained from lead, tin, and silver. Copper was widely used whereas only minor use was made of gold. After the Conquest, the Spaniards inventoried the arms, tools, and utensils that were found at Cusco and other important Inca sites. However, Ramusio's discussion refers mainly to metals that were semiproducts and had been held in reserve for trade with nearby communities that needed tin to make bronze. Storehouses with semimanufactured products were also found in other regions. In Colombia, warehouses were found that contained gold and copper semiproducts which had come from Mina Buritica (Trimborn, 1948).

The following data pertain to the distribution of tin ores which are commonly found in the vast area between Puno and Cajamarca (Petersen, 1960; 1969b). There are also cassiterite outcrops at Cerro Condoriquiña, to the northwest of Nevado Ananea (Dept. Puno). In 1933, during reconnaissance of a northwest extension of a granodiorite intrusion, "tin colors" were found in alluvial sands in the valley that runs from Paso de Aricoma to Limbani (Prov. Sandia). To the north, toward Vilcanota, cassiterite is found as float. Coarse-grained cassiterite is present in detrital material from the northern slopes of Nevado Ananea, in the general direction of Quiaca. Cassiterite has also been found in glaciofluvial material near Poto, Anccocala, and Huarasalani and may also be recovered from alluvial gold panning.

In Perú, tin is typically oxidized and may be found with copper and gold ores, as well as sulfides. For example, at Vilquechico and Huancané as Pb-stannite; at Mina Rosario and Lampa with copper minerals and stannite; at Cerro Pataoca and Cerro Accobina (Puno) as cassiterite; at Pachaconas, Antabamba, with gold; at Cerro de Pasco with argentiferous galena, pyrite, and acicular cassiterite; and at San Cristobal, Yauricocha, and Cobriza, as stannite (Bellido et al., 1969); at Los Tambillos, Chavin, with copper sulfides, argentiferous antimony, and as sulfides of tin; at Cajatambo and Santa Cruz (Prov. Santa Cruz), as cassiterite. In Queñamari, Carabaya, the cassiterite-bearing copper ores crop out in the oxidized zone (Ing. Fr. Langer, personal commun., 1965).

Lead

Lead is only rarely found as a native metal. In the gold-platinum sands in Choco, northwest Colombia, native lead may be found in 1 mm beads (Quiring, 1962; also see Chapter 8, Gold-Platinum). The common ore of lead is galena, and when it occurs with other metals, it is of economic importance. In ancient times, lead deposits were mined for their silver content. Color: lead gray with a grayish coating. Luster: metallic, slightly bluish. Streak: dark gray. Hardness: 1–2. Specific gravity: 11.35–11.37. Name in Quechua, *titi* or *tite* (Santo Tomás, 1560); *yanac titi* (González Holguín, 1608); *titi* (Middendorf, 1890). In Aymara, *titi* (Torres Rubio, 1616). Galena is called *sorojchi* or *soroche* and this term is also used to describe the veins that contain the ore as well as altitude sickness. The term *soroche* may also be used for ores similar in appearance to galena, such as antimony ores, as well as mixtures of pyrite, marcasite, and galena.

It is generally thought that ancient Peruvians did not specifically use or know about lead, however, lead ores were certainly a part of silver production. Baessler (1906) suggests that lead ores were used only after the arrival of the Spaniards, however, there is sufficient archaeological evidence to indicate that lead use is much older. In the Anthropology Museum (Berlin) are various lead objects (Schmidt, 1929, Fig. 396):

- Sample 13, a 5 cm diameter weight, from Pachacamac (Gretzner Collection).
- Sample 14, a bird that is 4.3 cm in height, from Ica (Baessler Collection).
- Sample 15, a 2 cm ball, with a fragment of string, from Pachacamac (Gretzner Collection).

Lead is not common in Mexico, however, it may have been used as an alloy with copper (Lothrop, 1953; Lothrop 1964).[9] Lead spoons are known in Colombia, Ecuador, and Perú. Lead discs that probably served as lids have also been found (J. Muelle, 1957, personal commun.). In the Museo Rafael Larco Herrera, in Lima, are lead objects from Moche time (Larco Hoyle, 1963). In the Museo Amano, in Miraflores, there is a conical lead object that is 3 cm in diameter and 3 cm in height. This piece comes from the Pisquillo Chico site in the Chancay Valley, approximately 10 km northeast of Huaral.

In the Museo Arqueológico Bruning, in Lambayeque, are five lead objects:

1. A *porra* (clubhead) with 4 points, height of 34 mm, maximum diameter 45 mm, central diameter 14 mm, and weighing 269 g.
2. A *porra* with 4 points, height of 24 mm, maximum diameter of 56 mm, lesser diameter of 50 mm, and weighing 234 g.
3. A *porra* with 4 points, cone-shaped with a 5 mm hole for a cord so that it could be used for throwing, weighing 142 g, 42 mm high, maximum dimension of 22 mm.
4. A cone-shaped lead piece, weighing 93 g, diameter 8–24 mm, height of 42 mm.
5. A rounded lead piece, with a concave base weighing 54 g, 25 mm high, maximum diameter 22 mm.

Sr. Oscar Fernández de Córdova Amézaga, Director of the Museum, recovered the five pieces on 16 June 1965 along with points and scrapers at the Rinconada de Cupisnique site, which is near Pampa de los Fósiles de Paiján (written commun., 10 September 1970). He considers these artifacts to have been used by hunters and to be from the Transitional Salina Mochica period. Sr. Fernández de Córdova Amézaga also provided information about a lead-silver container which was in the Museum and was obtained from excavations at La Ventana cemetery, Batán Grande, where it was found with Chimú ceramics (written commun., 9 November 1970).

Spectrographic analysis of the container was done at the Laboratorio Espectrográfico, Corporación Cerro de Pasco, La Oroya (Inf. 437, Lab no. XII-328–70, E. Manrique) and also at the Laboratorio de Análisis Químico Inorgánico, Universidad Nacional de Ingeniería (Cert. no. 25 873, 31 December 1970). The results are shown in Table 4 and indicate that the artifact is mainly lead.

"The quantities of gold, silver, copper, and lead found at Moche sites show that the metals were not only found in their native form and that the Moche also extracted metals from their ores. They knew and used cinnabar and we believe that they retorted mercury which was used for gold recovery. The presence of lead in the tombs shows that they were also able to separate this metal from silver processing" (Larco Hoyle, 1945b, p. 17).

Lead was occasionally used in the coastal regions of Ecuador where it was found with gold, for example at La Tolita. Meggers (1966) indicates that the Tolita period corresponds to

TABLE 4. ANALYSIS OF A LEAD CONTAINER, LA VENTANA (BATAN GRANDE), MUSEO BRUNING, LAMBAYEQUE

	Spectrographic analysis		Chemical analysis
Ag	V	Ag	0.001%
Al	V		
B	V		
Bi	V		
Ca	W		
Cu	W		
Fe	W		
Mg	V		
Mn	V		
Mo	V		
Na	V		
Ni	V		
Pb	M	Pb	98.7%
Sb	V		
Si	V	SiO_2	1.3%

Note: Analyzed for: 48 elements, Detected: 15 elements.
Key: M = >10%; W = 0.01–0.1%; V = < 0.01%.

approximately 500 B.C. to A.D. 500. In coastal Perú, lead appears in the archaeological record at about A.D. 200–300. In Central America, the Maya used lead from about A.D. 1000 and in the Altiplano (Bolivia) since about A.D. 1300. This date may be questionable because of the fact that native silver was mined before silver-bearing galena was processed. Artisanal metallurgists only produced about 30 g of silver, using charcoal for fuel. Tuyeres or blowpipes were used to extract silver which was alloyed with gold or copper, or used to gild copper and gold, or to solder gold with silver (Meggers, 1966).

Iron

Geologically, there are many iron occurrences in Perú and some of these were large and of economic importance.[10] However, for reasons discussed in the prologue, iron, as a metal, was not used in ancient Perú. Arsenical copper and bronze tools were of sufficient hardness and substituted for iron. And, ancient technology, only using charcoal, was not able to produce the high temperatures needed to reduce iron minerals to metal.[11]

In the bibliography, there are citations that say that ancient Peruvians used iron from meteorites, and therefore, metallic iron. These require a commentary from a regional historical perspective.[12] Regionally, meteors are rare in Perú and in the past 100 years there are only four recorded cases:

Atacama—meteor, surface scoracious and oxidized, with olivine, a lithosiderite (Raimondi, 1878).

Pampa Tamarugal, Iquique—meteor, compact, 81% iron, 18% nickel (Raimondi, 1878).

Atacama Desert—a meteor (Rivera Plaza, 1944, MGI no. 508).

Tambo Colorado—meteor, Dist. Leoncio Prado, Dept. Ayacucho, ovoid, 47 × 13 cm, 141 kg, 88.6% iron, 8.7% nickel, 0.03% cobalt (Freyre, 1950).

Given the exceptional number of archaeological artifacts known from ancient Perú, there are only two references to native iron; however, these are, thus far unsubstantiated. Rivero and Tschudi (1851, p. 321, figure 32) describe a very heavy vessel from Cusco, made of red jasper, in a rectangular shape, that was said to contain a piece of native iron. Muelle (1965, p. 6) found meteoritic iron at the Pachacamac site. Even given these descriptions, it is not quite correct to say that "iron" was known and used. And, very few people have seen the examples described.

Iron Minerals, Oxides, Hydroxides, and Sulfides

With the exception of the examples from Cusco and Pachacamac, only iron-bearing minerals or compounds were used in ancient Perú. The most important include:

Oxides—magnetite and hematite, in Quechua, *tacu*, meaning dark red; *ocre*, red; and *chumpi*, when the color is dark reddish-brown. Iron compounds were used before the arrival of the Spanish, however, mainly in Bolivia. Near Ancoraimes, a town in Prov. Omasuyos, are many large, well-known Inca mines that were visited. The metal from these mines was heavy and hard. It was dark-colored and did not shine. It gave a red color to the nearby stones and appeared to cement one to the other, as hematite. There was abundant iron based on other experiences. Perhaps, according to the ancient Peruvians, there was precious metal as well. Or, if this was not iron, it was taken to be used as ammunition. These were used in battles and called *higuayas* from the word *hihuaya* meaning a heavy dark rock which, when broken, has a red color (Alonso Barba, 1640, p. 52; Middendorf, 1890).

In the Museo Larco Herrera, several iron "balls" are on display. They are of different diameter and are magnetite. Perhaps there is some analogy between these and the magnetite balls that were taken from ancient burials in the Sierra Central (La Oroya region) that show signs of use and might have been used for tumbling or grinding (Ing. C. Richard Petersen, 1965, personal commun.).

At Litlic, near Lamud, Dept. Amazonas, an iron hatchet with 68% iron was found that appeared to be composed of hematite (Clement, 1938). It is now in the Museo Etnografico El Trocadero, Paris (no. 33.90.31). Similar tools of iron-hematite are also known from Bolivia and among these was a group of tools excavated from sites in the valleys east of Cochabamba and northeast of Chuquisaca (Ibarra Grasso, 1960). Most of these were purchased, however, four similar appearing hatchets were found at an archaeological site that corresponded with the Chavin of Perú. The site is M-510, Cliza, Bolivia which has a ^{14}C date of 1,680 ± 300 yr[13].

Hydroxides—goethite, limonite, and ochres, in Quechua, *'kellu* or *quellu*, yellow or yellow-orange. In ancient Perú, a great volume of oxidized iron compounds were used to decorate the temples and other buildings, for example at Cerro Culebra in the Rio Chillón valley (Stumer, 1954), at Moche (Kroeber, 1930), Pachacamac (Muelle and Wells, 1939), and Pañamarca (Schaedel, 1951; Bonavia, 1959). Many other sites also have polychromatic murals. For more details, see section on Ochres and Pigments.

Sulfides—pyrite, in Quechua, *carhua llimpi*, ground pyrite; *carhua*, yellow thing; *llimpi*, powder, dust. Pyrite was used for making mirrors (Schmidt, 1929). Also see Chapter 10 (Mirrors). Powdered pyrite, called *carhuanuqui*, was also been used for religious ceremonies as well as burials. Pieces of pyrite, along with charcoal and ceramics, were found at the metalshop at the Yécala site (Vicús, Piura). Charcoal from the pyrite-bearing layer gave a ^{14}C date that was approximately A.D. 300–400 (H.D. Disselhoff, personal commun., June 20, 1967; Petersen, 1969). Data on this ^{14}C date are given in "Seis Fechas Radiocarbónicas de Vicús" (Disselhoff, 1969). The dates are: A.D. 250 ± 110; 410 ± 60; 425 ± 115; 460 ± 70; and 655 ± 100 yr depending on the depth of the strata from which the samples were taken.

According to Rowe (1946, p. 246), the Quechua word for iron, *quellay*, probably refers to meteoritic iron or compounds such as hematite. There is no evidence that the Incas knew how to smelt iron. Alcina Franch (1970, p. 319) cites Rowe (1946, p. 246) and says that the Incas knew about iron and that there was a Quechua word, *quellay*, for iron. The absence of iron in the archaeological record indicates that ancient Peruvians neither smelted nor used metallic iron. This can also be inferred from the fact that there is no word for something which was not used. Additionally, there are abundant words for the compounds of iron and the other metals and minerals that were used daily. In the Santo Tomás (1560) Quechua dictionary, the word *quillay* is used for metallic iron; however, this is likely a neo-Quechuismo or a word made by translation or casual use. Twenty five years after the Conquest, when the dictionary was compiled, it is likely that by then, a Quechua word was used to describe the iron that was known to be used by the Spaniards. This use has continued in later dictionaries, for example, Ricardo (1586). In the González Holguín (1608) dictionary are found the words *quellay tacay huaci*, ironworking, and *qquillay tacal*, blacksmith, words that logically did not exist before European contact that came into use after European contact. To reinforce this idea, there is a usage that is especially important. None of Perú's numerous iron occurrences that are described in endnote 10 include the word *quillay*, which should have been used if the site were an iron occurrence. The eight prefixes combined with *quillay* and found in geographic dictionaries, for example, Paz Soldán (1877) and Stiglich (1922) do not indicate "metal" with the exception of one word that that roughly translates to silver or copper ores and smelter scoria. Therefore, it seems that *quillay* originally had a different meaning. Lira (1945), for example, used *killay*, for a plant used for soap. Other similar-sounding words include *kkellay aka*, meaning rust, and *kkhellay*, meaning to clean grain, minerals, or remove slag. In Dept. Ancash, *quellai* refers to silver (Dra. R. Rivera, 1967, oral commun.). Therefore, the indigenous words *quillay*, *quillai*, or *quellay* cannot be interpreted to indicate the knowledge or use of iron in Perú before European contact.

Platinum

Ultrabasic rocks are the source of platinum, however, through weathering and erosion, platinum may also be found in alluvial occurrences. Native platinum is rarely pure and may be found in natural alloys with varying amounts of iridium, osmium, rhodium, and palladium. Platinum may be recovered from alluvial deposits using small-scale methods, such as a *batea*, or on a larger-scale. Color: gray to tin-white. Luster: metallic white. Streak: silvery white. Hardness: 4.0–4.5. Specific gravity: 21.4–21.48. Platinum is malleable.

Bolivia

Trace amounts of platinum have been found in alluvial deposits in Prov. Nuflo de Chávez and at Mina Pacajake (silver), which is near Colquechaca, as the rare mineral bloquite (Ni, Cu, Se_2 with 0.138% platinum and 0.007% pallidium) (Ahlfeld and Muñoz Reyes, 1955, p. 68). A sample of silver obtained by fusion of bloquite contained 0.4% palladium, 0.2% platinum, 0.03% rhenium, and 0.1% gold (Quiring, 1962).

Chile

In the gold placers in the western shores of Chiloé Island, gold, platinum, and other heavy minerals may be found. Platinum may be found in peridotites near Rio Velásquez in the Cormean Peninsula and in alluvial deposits in the Cordillera de San Fernando in central Chile (Quiring, 1962).

Colombia

Platinum may be found with alluvial gold deposits in the northwest part of Colombia, Intendencia de Chocó, along the Rios Atrato and San Juan. The deposits are alluvial, in terrace gravels, or in caliche. Platinum is found in black sands that include magnetite, pyrite, chromite, spinel, limonite, garnet, olivine, epidote, hornblende, quartz, and zircon. Native lead, native copper, and alloys of native gold and silver may also be present. Separation of gold from platinum is a difficult process, but this was apparently accomplished during ancient times. A platinum nugget that weighed approximately 900 g (85% platinum) was found in the Valle Chocó and another which weighed approximately 520 g was found near Istamina. The largest nugget found in the world weighed 11.641 kg. It was from Nueva Granada, Colombia and is now in the Museo de Madrid (Quiring, 1962). Gold-platinum sands, which may contain 0.1–1 g/m^3 platinum, are worked using boats with suction hoses and the platinum may occur in grains and flakes (Friedensburg, 1965).

Ecuador

Quiring (1962) gave a summary of the data available on the presence of platinum in Ecuador. The gold placers of the Rios Bogotá, Cachabi, Uimbi, Santiago, and Cayápas contain platinum (A.D. Lump, *The Platinum Metals*, London, 1920, p. 58). The gold-platinum placers in Esmeraldas were probably mined before European contact. In the Manabí region, along the coast of Esmeraldas, and near La Tolita and Atacames in central Ecuador, jewelry, and other artifacts were found that contained 55%–60% platinum, 35%–40% gold, and silver (P. Bergsoe, The Metallurgy and Technology of Gold and Platinum Among the Pre-Columbian Indians, Ingenioeruvidenks, Skr. Koebenhavn No. A 44, 1937). Alloying was done using a blowpipe. A comparison of the chemical composition of alluvial platinum from Colombia and Ecuador is given in Table 6.

This information is based on the studies of Wolf (1892, p. 322–329). The platinum content of the electrum from Rio Sayapito is 17.46% platinum, however, Wolf indicates that the amount might reach 25% if the alluvial material is carefully washed. The platinum content of six electrum samples from several rivers in Prov. Esmeraldas, and given in Table 5, was compiled from Wolf (1892, p. 328).

A small ingot of platinum was found in Lagarto, Ecuador, and platinum jewelry was reported from La Tolita (Wolf, 1879). These artifacts were apparently made from alluvial material with very high platinum content (Table 6).

Composition of alluvial platinum. G. de Créquit-Monfort and P. Rivet (1919) also published analyses of platinum-bearing alluvial gold:

	Au%	Ag%	Pt%	Impurities%
Rio Sapayito	69.57	11.60	17.46	1.37
Playa de Oro	75.72	11.33	10.91	2.02
Rio Uimbo	80.79	12.20	3.15	3.86
Rio Cachabi	82.84	13.84	1.19	2.13

TABLE 5. ANALYSES OF ALLUVIAL SILVER-PLATINUM-GOLD FROM PROV. ESMERALDAS, ECUADOR[1]

	Rio Cayapas (%)	Rio Sapayito (%)	Playa de Oro (%)	Rio Uimbo (%)	Rio Cachabi (%)	Rio Bogota (%)
Au (electrum)	98.3	81.2	87.1	93.0	96.7	97.8
Pt, PGM	–	17.5	10.9	3.1	1.2	–
Impurities	1.7	1.4	2.0	3.9	2.1	2.2
Au (pure)	87.4	85.7	87.0	86.9	85.7	86.7
Ag (alloy)	12.6	14.3	13.0	13.1	14.3	13.3
Carats	21	20.5	21	21	20.5	21

[1]Wolf (1879, p. 328).
PGM—platinum group metal.

TABLE 6. ANALYSES OF ALLUVIAL PLATINUM FROM COLOMBIA AND ECUADOR

	Chocó, Colombia[1] %	Chocó, Colombia[1] %	Chocó, Colombia[1] %	Chocó, Colombia[1] %	Sapayito, Ecuador[2] %
Pt	84.97	85.0	86.2	76.82	84.95
Pl	0.7	0.5–1.0	0.5	1.14	–
Rh	0.79	1.4–3.5	1.4	1.22	4.64
Ir	1.16	–	0.85	1.18	–
Os	0.42	0.5–1.5	0.95	7.98	1.54
Fe	–	5.8	7.8	7.43	6.94
Au	–	–	–	–	1.12
Cu	–	–	0.6	0.88	tr.
Ag	–	–	–	–	tr.
Impurities	–	–	–	–	0.81

[1]Quiring (1962).
[2]Wolf (1879).

Perú

Rio Santiago. Gold-bearing alluvial material from the Rio Santiago, in the eastern part of Perú, has been worked since the seventeenth century and very likely was worked before European contact. Miller and Singewald (1919, p. 405) note that these alluvial deposits also contain platinum; however, the quantity is not sufficient to be economic.

Piura-Tumbes. In pre-Columbian graves at Los Organos, between Piura and Tumbes, Chimú lip jewelry was analyzed and found to contain traces of palladium and platinum (Petersen, 1955). The analyses were done in the Laboratorio Espectrográfico, Corporación Cerro de Pasco, La Oroya (Inf. no. 452, E. Manrique, 21.12.70). See Table 18, this report.

Lambayeque. In 1942, treasure hunters working in Lambayeque found a small, hard, yellowish piece of flattened metal that was thought to be a platinum alloy (La Prensa, Lima, March 16, 1966).

Cerro de Pasco. Blister copper from Cerro de Pasco was found to contain trace amounts of palladium and platinum. For every 100 tons of copper produced, 0.589 ounces of palladium and 0.319 ounces of platinum were recovered from the slimes at the refinery (Eilers, 1914). Spectrographic analyses also indicated that copper from Yauricocha and Cobriza contained 0.01%–0.1% palladium (Table 7).

Paracas. In a compilation of analyses of metals from Perú, Lothrop (1953, Table 2) describes an ornament from Paracas that has 77.0% gold, 19.0% silver, and 4.0% copper with trace amounts of platinum. In southern Perú, almost all the metal objects of the Paracas and Nazca period are of hammered gold that is relatively pure, however, in the north, the gold is a different quality and contains silver and minor amounts of platinum.

Cusco. Platinum was found in samples from a mineralized outcrop at San Cipriano, near the Colca Hacienda (Quillabamba), Dept. Cusco. The outcrop was an unweathered gabbro that contained irregular bodies of pyrrhotite, chalcopyrite, with nickel, gold, and platinum (Kiilsgaard and Bellido, 1959).

CHAPTER 4

Mining

The interrelationship of mineralized rock, minerals, ores, rocks, and metals used by ancient Peruvians is impressive for its complexity and diversity. Significant human effort went into mining and mineral production in ancient Perú. Both open pit and underground methods were widely used. This is directly evidenced by finds of tools and other equipment left by the miners at their work sites. European writings which date to the beginning of the Colonial period, as well as modern research, document mining methods in ancient Perú. In some cases the data provided is generalized, and in other cases, the references are very specific. Some sites were mined before, as well as during, the broadly defined Inca period. Some of these ancient sites were abandoned and later rediscovered by the Spaniards, for example, the cinnabar mines at Huancavelica. Presented below are sites in Perú that were worked before the arrival of the Spanish.

ANCIENT MINING CAMPS

Bolivia

Andacaba; Ancoraimes, Omasuyos; Berenguela; Carabuco, Camacho; Caramgas; Charcas; Chincas; Choquepiña; Pacajes; Chungamayo; Chuquiyapu (La Paz), Chuquiaguillo (La Paz); Chucuito. Larecaja; Corocoro; Curaguara del Pacajes; Cerro Descuelga, Illimani; Cerro Escapi (Chuyca); Lipez; Cerro de la Plata, Oruru; Porco; Salbacha, Sisasica; Tarabuco, Tiahuanaco; Turco; Vilaque (Tiahuanaco) Yulloma.

Wendt (1890) writes that all the silver mines now active in Bolivia were worked by the Spaniards and earlier, by the Inca, well before the arrival of the Spaniards. The great quantity of silver held by the Incas at the time of the Conquest, as well as their mines, indicate how advanced they were in mining and metallurgy. Many adits, hundreds of feet in length, were excavated in solid rock using only chisels and other simple tools. These adits were straight and well-made as if they were done today.

Piles of ancient slag that can be seen throughout Bolivia show that galena was smelted and cuppellation was practiced. Today, in Bolivia, only the descendants of the ancient miners and smelters know how to smelt galena in the primitive ovens.

Chile

Almirante Latorre, Cu, Ag, Au; Caleta El Cobre, Cu; Camarones, Au, Cu; Carrizal Alto, Cu; Cerro Blanco, Au; Challinga-Hacienda Agustín, Cu; Chuquicamata, Cu; El Nogal; El Salvador (also known as Indio Muerto), Cu; El Zapallo, Au, Cu; Fierro Carrera; Huantajaya, Ag; La Serena; La Isla; Los Puntiudos; Los Infieles; Quebrada de Talco, Au; Quillagua; San Bartolo, Cu; Sierra El Salto; Toconao; Yabricoya, Ag (Solari, 1967).

Perú

Ananea, Puno; Anccocala, Puno; Ayamaya; Apurimac; Cachicachi; Callana; Rio Grande or San Juan del Oro; Calvas; Canza, Ica; Caylloma; Carabaya; Castrovirreyna; Cerro de Pasco; Chachapoyas; Challhuanaca; Chincha; Chinchipe; Chinihuaya (Tambopata); ChococVocha; Chunchusmayo; Chuquaiara; Colquemarca; Cajamarca; Colquijirca; Condoroma; Curamba; Cusco; Guanesa (Huánuco Viejo); Hoabamba (Huayna Picchu); Hualgayoc; Huancavelica; Ica; Iparo; Sandia; Lampa; Llamillami, Llenque, Tambopata; Cerro Lin, Micuipampa; Rio Marañon; Morona; Navar, Cajamarca; Nazca; Ocoña; Patáz; Poto (Puno); Paucartambo, Cusco; Pomasi; Puyango, Ricaplaya, Rio Tumbes; Sacsaquero; San Antonio de Esquilache; San Cristóbal; San Gabán; Sandia; Santa Rosa; Santa Lucia; Santa; Santiago, Rio Tambopata; Vetasmayo (Tambopata); Vilcabamba; Yanacancha, Pasco; Yauricocha, Pasco; Cusimayu, Cajamarca; Chuquiyacu; Palcas.

OPEN-PIT MINING

Alluvial Occurrences

Open-pit mining methods vary depending on the resources that are to be extracted. As previously described, gold is mainly found in alluvial deposits in rivers, streams, or in glaciofluvial occurrences. Alluvial silver and mercury is commonly found with up-slope vein occurrences.

Mineralized Veins

Silver mining, before the arrival of the Spaniards, was done at oxidized outcrops containing lead-silver veins. Typically, these were brightly colored, reddened, oxidized outcrops that were also called “iron hat” or in Quechua, *pacos*. This style of mining was very easy for the ancient miner. In the early years of colonization, the Spanish wrote about the ancient mining practices. For example, at Porco, Bolivia, a well-known Inca mining site, the metal was extracted and described as bricks of white silver which only had to be struck with a tool to remove the metal from the outcrop, much like a silver adobe brick. The silver was mostly white and pure in the mines and in veins, referred to as *machado* which is a Peruvian field term indicating that visible gold or silver is present. The minerals were as they had been in the mines in Prov. Carangas. At Choquepiña, another Inca site two leagues from Berenguela (Prov. Pacajes) and a half league from San Cristobal, in Prov. Los Lipez and in almost all of the mines of this region, ore of this type was found, all with veins of silver. However, no other minerals appear this way. At Oruru, as at San Cristobal, pure silver was seen in the rocks or *corpas*. This was a district rich with *llampos*, or silver in powder form that only had to be separated by washing and could be mined much like gold (Alonso Barba, 1640/1967, p. 47). In Quechua, *llampu* means smooth or polished.

Copper was found in rocks which were a variety of colors, but almost always with a blue or green color, and was also found with gold and silver. It was easy to follow veins of pure copper that oftentimes had rich pockets of pure gold. Silver is mixed with copper and must be found by trial and error as the veins continue to depth where the mineralizing fluids must have been richer in metal. Mina Oslloque, in Lipez, which at depth contained silver of a purity that is rarely seen. Also at Lipez are ancient workings at Cerro Escapa, which is two leagues from Chuyca, and in the Altos de Tarabuco, there are many diggings and ancient mine workings. Also near Curaguara de Pacajes, there are ancient mines from which veined rock with visible gold or silver (*machacado*) can be taken (Alonso Barba, 1640/1967, p. 47).

UNDERGROUND WORKINGS

Before the arrival of the Spaniards, and because of a variety of engineering constraints, ancient mining rarely took place to great depths or distances. These mines were worked only as far as the light of day could reach. There are, however, a few exceptions, such as alluvial deposits which occasionally had adits up to 70 m in length. The openings to these mines were usually very restricted and low requiring the miner to crawl inside. These early mines were not ventilated or dewatered.

The ancient miner usually worked the softer rocks such as sandstone, lutites, and slates and rarely worked the igneous and metamorphic rocks. Wear on the mining tools was especially great in gravelly units. As a consequence of these limitations, the ancient miner typically opened many adits instead of opening a single deep adit. This is why numerous small mines are found on the slopes of Descuelga, Nevado Illimani, and Micuipampa.

MINING METHODS

In underground mining, it was common to set a blazing fire at the mineralized zone, then quench the rock face with water, and then remove the cracked and broken rock using larger rocks or hammerstones. Baskets made of woven sticks were used to remove the larger rocks. The ore was transported in backpacks or on slings of leather stretched between sticks. The crushing plant was usually near a stream where the ore could be crushed by using a large, rocking stone called a *quimbalete*. The ore was concentrated using water in a conical wooden bowl, or *batea*. During the time of the Inca, native metals were moved on, daily, to the Inca authorities. Copper and tin ores were treated by metallurgical methods in order to obtain the pure metal.

MINING TOOLS

In different mines and sites with evidence of ancient mining activity, the variety of tools and accessories gives an idea of the many implements that were needed to extract the mineral riches:

Stone Implements

Chisels, up to 28 cm in length have been found at Inca and Diaguita-Chilena sites, large baskets were also found.
Hatchets, made of flint.
Hammers, made of granodiorite, diorite, fine-grained granite, and others, may be round and up to 6 cm in diameter.
Scraper, made of basalt (Disselhoff, 1969b).
Maul, made of igneous rock, hafted, with a wooden handle.
Mortar, made of a variety of igneous rocks.
Crusher, a mill used to pulverize minerals. Figure 10, nos. 5–9, also called "Inca mill," *quimbalete*, *bimbalete*, or *bambalete*, from the words meaning shake or moving from one side to the other while staying in the same place. This crusher consists of two parts, a lower stationary part of granite or possibly metamorphosed rock and the larger, movable part, the *quimbalete*, which is rocked back and forth using one or two strong poles that are rocked by the workers. The upper part is usually of igneous rock and may be a block, or shaped like a truncated pyramid, or a half-moon. It may be 1 m high and 0.5 m wide, and can be very simple or elaborate (Figs. 2, 10). The rocking sticks may be alongside the block or strapped on top. There are examples showing that a plank has been placed on top which allows one person to walk back and forth, and thereby move the crusher (Ahlfeld and Schneider-Scherbina, 1964, fig. 101). Helmer (1962, fig. 2) showed another style. There are a variety of descriptions given by Alonso Barba (1640), Bargalló (1955; 1969, figs. 28, 29), Helmer (1962), Rivero (1857), Romaña (1908, fig. 26), Olaechea (1901, p. 9). Also *piruro*, meaning drum wheel. There are many examples of artisanal crushing mills, or *quimbaletes*, at:
- Argentina:
  - Rioja, Uspallata, Prov. Mendoza
- Bolivia:
  - Mina San José, Oruru; Potosí.
- Chile:
  - Rinconada, Pompeya, Prov. Catamarca; Sierra de Capillitas, Dept. Tingogaste, Prov. San Juan and San Pedro de Atacama; Cobres, Diaguita Region (Bowman, written commun., 1966).
- Perú:
  - Rinconada de San Francisco, Nevado Ananea; Mayokunka, Sina (Prov. Sandia); Q. Matarani (Chala);

other names and sources of information include *quimbalete*, *macate* (Prov. Huaylas) (Paz Soldán, 1877); Stiglich, 1922; *quimbaletes* (Dist. Puyo, Parinacochas).

Name in Quechua—In recent bibliographies, the term *maray*, was erroneously used for the *quimbalete*. *Maray* refers to the lower crushing stone only. However, Santo Tomás (1560) used *maray* or *maran* for the upper stone that is rocked back and forth. González Holguín (1608) used *maray* or *maran* for the lower stone and *wrcun* or *tuna* for the upper stone (from *tuna*, meaning high or above). Lira (1945) used *maran*, or flat rock for crushing. Perroud and Chouvenc (1970) used *tunai* for the upper rock and *marai* for the lower rock. Others used *jollota* or *julluta* for the upper rock and *muchka* for the lower rock, also *mu't'ka*. Olaechea (1901, p. 9) cites use of the word *konacho* for the lower stone and F.C. Fuchs (oral commun., 1968) notes more than a thousand *quimbaletes*, or *konachos*, were found near Hacienda Trapiche, Cochasayhuas, Prov. Cotabamba, Dept. Apurimac. This word is probably related to *'konj* or mill, *'konay* or mortar, *'konay-chiy* to grind, *kenuy* to grind on a surface (Middendorf, 1890); *kkhonaw* or *kkhona*, cylindrical stone for grinding, a pestle, *kkhonawa*, *kkaniwa*, a flat stone used from grinding, *kkonay*, to pulverize (Lira, 1945).

Metal

Hammers, copper or bronze, different shapes.
Hatchet, copper.
Digging poles, copper or bronze. Storehouses with digging poles, which were used for mining, were found in Cusco (Diego de Trujillo, 1571[1948]); circular rods were also found (Hesse, 1969). Blowpipes, copper tubes of different lengths were used to intensify the heat in smelting ovens and for crucibles.

Ceramic

At Chiripa, long ceramic tubes were found, generally of the same shape, decorated in relief on the exterior and with incisement, which, with a little imagination, could be seen as trumpets or pipes. However, these were used as blowpipes to intensify the fires of the smelters and are very similar to those that are used today by the Aymara and are called *phusaña*. This type of artifact has also been found at Tiwanaku I and at Wankarani and it is important to note that these cultures were also at the Formative period in the Bolivian Altiplano. Other examples are from Tiahuanaco, La Paz, and Pucará (Ponce Sanginés, 1970, p. 55, fig. 30).

Horn and Bone

Picks and scrapers. These were made of hard deer antlers and also from the iliac of deer and llamas and were first described by A.A. (1952, Fig. 11). A pick from the Chavin period, now in the Museo Arqueología de la Universidad Nacional Mayor de San Marcos, was described by Fung (1969, p. 44). It was 20 cm in length, was worn down, with a cane handle tied with cord and came from Las Aldas, which is approximately 26 km south of Casma. In coastal Perú, whale bones were used for chisels as well as for baskets (Engel, 1958).

Deer from the Andes were hunted in ancient times for meat and the antlers and bone provided material for tools. Two species were especially important:

- Andean deer (**Ciervo andino**), originally described by Tschudi and Pucherón (unreferenced) as **Cervus antisiensis** and later classified as **Hippocamelus antisiensis** (Cabrera and Yépes, 1960). It is brown, typically lives above 4000 m in small groups, and has two antlers, each of which is forked. This deer is typically 1.60 m long and 1 m in height.
- **Ococoileus peruvianus** (Behrendt, 1960). It lives between the jungle and the coast at elevations of 100–3800 m and has two antlers of two to three forks that are replaced annually. Its height is 0.8 m.

Commonly used names include: stag, *taruca*, *huemul* of the north, buck, deer, **Cariacu peruano**, *taruya*, *tarugón*, and *tarus* (Tschudi, 1891). In Quechua, the name for the Andean deer is *lluycho*, *taroca* (Santo Tomás, 1560); *taruca* (González Holguín, 1608); *taruca*, *lluycho* (Tschudi, 1891); *tarukha*, *tarrukka* (Lira, 1945); *taruka*, *salkka*, *luychu* (Perroud and Chouvenc, 1970); *luicho*, *taruka* (Ricardo, 1586); *luychu*, *har'qo taruka* (Middendorf, 1890); *taruca*, *luichu* (Guardia Mayorga, 1967); *tallu*, *tallus* (Perroud and Chouvenc, 1970). In Aymara, *tarukha*, *l'uytsu* (Bertoni, 1612); *taruca*, *taruja* (Torres Rubio, 1616).

Llama, *lama huanaco* (**Llama guanicoe**); *lama paco* (**Llama alpaca**); also *paco*, *pacocha*.

Wood and Other Materials

Cradle, made of hard wood, typically **Polilepsis sp.**
Logs, typically made of the same type of wood, were used for ladders, bridges, general construction as well as supports in the mines.
Wooden bowl, or *batea*, used to concentrate gold.
Digging stick, of wood with a copper sheath.
Baskets, made of sticks and twigs of mimbre or sugar cane.
Poles, used to rock the *quimbaletes*.
Sacks, made of cured or uncured leather, used to carry ore.
Level, made of wood, in Quechua, *chunta*, found in a burial in Ancón (Saenz, 1892; Carranza, 1922), a cylindrical rod 30 cm long and 2 cm in diameter, with two channels on opposite sides that join in the center of the cylinder in which a ball of hardened clay is used to indicate that the instrument is horizontal. During Inca time circular levels, with water, were used. An instrument of this type was found in 1965 by F. Belaunde Terry and is now in the Museo Arqueológico de Huaráz. A photograph was published in the newspaper *La Prensa* (no. 24, 408) on 19 August 1965.

Metal tape measure, in Quechua, *wincha*, *huincha*, or *bincha*. Valcárcel (1935, written commun.) described a silver tape measure with clasps, one of which was broken. The tape was 3.12 m long, 2.0 cm wide, weighed 180 g, and it was probably much longer.

SITES WHERE ANCIENT MINING TOOLS HAVE BEEN FOUND

Perú

Cerro Chacllatana, Huancavelica, bone tools, grinding stones; *quimbaletes* at Macate, Parinacochas.

Cerro Huamanripa, Yauricocha (Cerro de Pasco), tools (A.A., 1953).

Machu Picchu, charcoal hearth used to work bronze (Bingham, 1948, p. 42–43). At Quebrada Matarani, 40 km northeast of Chala, 60 *quimbaletes* were found (Olaechea, 1887) and at Mayokunka, Sandia, two *quimbaletes* were found.

Quispejahuar and Quispesica, Castrovirreyna, a variety of tools and an obsidian quarry.

San Francisco, Nevado Ananea, Puno.

Argentina

Rioja and Uspallata, (Mendoza), *quimbaletes*.

Bolivia

Cerro Descuelaga, Nevado Illimani, tools.

Potosí.

San José, Oruru, *quimbalete*.

Chile

Chuquicamata, tools, goods, mummy of a miner who died accidentally. In the small workings, or *lamperas*, tools of bone and rock were found (Acosta et al., 1954).

Cobre, Rinconada, Pompeya (Catamarca) Los Infieles, Coquimbo, baskets, hammers, ceramics, and chisels.

San Pedro de Atacama, *quimbalete*.

Sierra de Capillitas (Tinogate), *quimbalete*.

Talca (Coquimbo), 2 km from the mine, copper and stone tools were found, also a *quimbalete*.

Quillagua and San Bartolo (Antofagasta), wooden-handled quartzite and fine-grained granite hammers (Solari, 1967).

El Nogal, Los Puntiudos, Fierro Carrera, Los Infieles, and La Serena, large stick-baskets for carrying rock, assorted tools of considerable size and weight, hammerstones 6 cm across and chisels as long as 28 cm were found in context with ceramics from the Diaguita-Chilena period to Inca time (Iribarren, 1962).

CHAPTER 5

The Chuquicamata Mummy, an Ancient Mining Accident

Mining in ancient time was dangerous and this is documented by the find of the mummified body of a miner at Mina Chuquicamata (copper), near Calama, Prov. Antofagasta, Chile.[14] In October 1899, Mauricio Pidot, a French mining engineer was working at a shallow trench that collapsed because of the nature of the soil. The collapse left a small opening through which he saw the foot of a body. After cleaning up the body and removing rocks and other material that clung to the body, Pidot sold his find to Eduardo Jackson, the manager of Mina Caracoles for an unknown amount. The mummy was found at a depth of no more than 2–3 m and it is likely that the miner was buried by an earthquake as he was working. Upon having the rocks and earth come down on him, the miner tried to protect his head with his arms and hands and it was in this position that he was found.

The mummy appeared to be of a strong individual, however, because of the hips, the braided hair, the appearance of the face, and despite having lost the nose during the collapse, it was first thought that the mummy might have been that of a woman. This appeared to be anomalous with that which was known about gender roles in ancient mining.

The muscles of the arms and legs appeared to be deformed. However, this was likely caused by the weight of the collapsed material and the effect of the rocks that had become encrusted in the tissue. In various parts of the body, different colors of skin suggested that tissue had been damaged by the rockfall which had resulted in blood collecting in the damaged tissue. The head was hidden by the arms, the mouth was tightly shut, and blood had come from the ears. The legs were drawn up, one under the other, as if to protect his upper body.

The hair had been carefully braided and the eyebrows were well preserved. The miner wore a coarse belt made of *llama* skin that still had the wool attached. The miner's ankles had bracelets of similar material which had become green because of the copper oxides in the mine.

Given the position in which the mummy was preserved, it is not easy to give an exact height, however, five feet and seven inches seems reasonable. Regardless, for the time, the individual was of large size, strong, and well formed.

The miner was found with a small basket in his hand and another larger basket was found at his side. A leather apron, a stone hatchet, and several hammerstones with wooden handles attached with llama skin were also found. The mummy eventually went to the American Museum of Natural History along with its hammerstones and baskets full of atacamite (copper ore) (Root, 1949a).

"Copper Man," as the mummy was referred to, became one of the more interesting finds in Latin America (Ladd, 1957, p. 12). The mummified body was later clearly identified as having been an adult male who died working at the mine, and according to Dr. Junius Bird, Director of the Museum, the artifacts found with "Copper Man" such as the hammerstones and belt, left little doubt that the miner lived and died before the arrival of the Spaniards.

Upon an invitation from Dr. Bird in 1953, Dr. Charles Milton of the George Washington University and I had the good fortune to study "Copper Man" at the Museum. The exterior of the mummy was well-preserved; however, the interior was empty. This cavity was apparent when samples were taken for examination. A sample of dried tissue, apparently deeply stained with copper, and another sample with no evidence of copper replacement were taken. Thin-sections of the skin and underlying tissues were prepared by Dr. T.M. Peery of the George Washington University Hospital, Washington, D.C. The slides were examined by standard methods, however, neither sample showed any indication of mineral deposition, or replacement in the tissues. It was Dr. Peery's opinion that the preservation of the mummy was a simple case of desiccation without bacterial decomposition.

Dr. Bird shared a copy of a letter, dated 25 January 1965, to Ms. Gertrude Nichols of Chicago that gave more information on the "Copper Man." In the letter, he indicated that Florence Swan's description of the "Copper Man" was exaggerated. He is not a mass of solid copper; indeed, on the surface of the skin there was very little copper or copper compounds. The copper salts provided a powerful bacteriocide and fungicide which would not have been suitable for everyday medical use. The fact that "Copper Man" worked in one of the driest regions of the world, the Atacama Desert, and that the weight of the debris increased the blood in the head and in the extremities during the initial drying out of the body, caused the body to be well-preserved and, therefore, appear much as he did when alive. Because the miner's hair was long and braided, it was initially thought to have been the body of a woman. The miner was essentially naked except for a belt around his waist. The material of this belt made it easy to establish the fact that his death had occurred before European contact.

Dr. Bird had more information to share on the find of the mummy. At first, it was discussed that the mummy belonged to the mine operator whose legal right extended to the minerals. Therefore, the operator claimed that since the body was mineralized, it belonged to him. The mine owners disagreed. Finally, the mummy was sold and exhibited in Santiago de Chile, then at the Buffalo Exhibition; however, certain bills were not paid and the body was returned to the Chilean Consulate. In 1905, the bills were settled by J.P. Morgan and the mummy was given to the Natural History Museum of New York.

"Copper Man" is a mute testament to human tragedy and a symbol of uncounted generations and sacrifices during millenniums of ancient mining.

CHAPTER 6

Inca Mining in the Altiplano

In the presence of the almost unthinkable ransom given for Atahualpa, the Spaniards wanted to know more about the source of these riches. They had heard that the gold came from Collao; this information that was provided by "Anónimo de Sevilla, 1534" and was included in the book *Crónica de la Conquista del Perú* [*Cronicles of the Conquest of Perú*].[15]

Pedro Sancho de la Hoz (1938, p. 180), in Chapter XVIII of his documentation of the Conquest, wrote that "In this way, the Governor and his forces entered the grand city of Cusco without any battles or resistance, on Friday at the time of the high mass, the 15th of November of the year MDXXXIII of our Lord Jesus Christ…the following day the Governor and this son of Guainacaba, who was described as an intelligent, prudent man, required that all the chiefs of the region obey the Governor and do as he demanded."

Francisco Pizarro, upon finding himself in Cusco at the end of 1533 and during the first months of 1534, took the opportunity to send an exploration team to the Collao gold district which generally included the Altiplano of Perú and Bolivia. The expedition leaders, Diego de Aguero and Pedro Martinez de Moguer (Pedro Pizarro) also explored other unknown areas that were indirectly a part of the territory.[16]

Sancho de la Hoz (1938) wrote that the two explorers who had been sent to explore the Collao territory for forty days returned to the city of Cusco where the Governor was and related all that they had seen and learned. Their observations are included in the following:

> The Collao territory is quite far away and distant from the ocean, in fact, the inhabitants know very little of the ocean. The mountains are high, fairly open, and it is exceptionally cold. There is no forest nor is there wood to burn. However, wood is obtained through trade from those who live closer to the ocean and are called Ingres. Wood is also obtained from those who live at lower elevations near the rivers who trade wood for sheep, other animals, and vegetables. Otherwise the land is essentially sterile and they live on roots, herbs, corn, and sometimes meat. In the Collao territory, there are not many sheep. The inhabitants are subject to the will of their gods and to the Governor to whom they owe their obedience; for example, no animals may be killed without permission from the gods or the Governor. The territory is generally well-populated and the population has not been affected by the battles that took place in other regions. The towns are of average size and the dwellings are small and made of adobe and stone walls with a roof of straw. The plants that grow there are short and sparse. There are only a few rivers and these are shallow and of low volume. In the middle of the territory is a large lake [Lake Titicaca] and the most populated areas are along the shores of the lake. The rich mines of Collao territory are some distance from this lake which is called Chuchiabo. It is these mines that are in a river canyon, perhaps halfway up the sides of the canyon, and appear to be caves from which the material is taken. Mining is done with deer antlers and the ore and other material is taken from the mines in sacks sewn from leather or sheepskin. The ore is washed in the same river at places where there are smooth flat stones upon which the ore is placed. Water from a small channel is directed upon the ore and, with a little luck, gold may be recovered. The mines themselves go into the hill some 10–20 m and the most important mine, called Guarnacabo, goes for 40 m. None of these mines are lighted and they are very narrow so that a person must squeeze in and there is little room for another to enter. There are about fifty men and women working at this mine. In other places there are twenty, at another fifty, and at another, perhaps thirty. Ore is mined for a chief and there is a stronghold so that no one can rob them of the gold that they have mined. Near the mines are other guarded strongholds so that no one can steal gold or leave without being seen. At night, when the miners return to their towns, they enter through a gate where the managers responsible for the gold receive from each miner the gold that has been mined.
>
> There are other mines located sparsely throughout the territory that are about the depth of a man and are more like wells from which the dirt is taken to the top. And, when these cave in, they are abandoned and other pits are made. However, the richest, and those from which the most gold is taken, are of the type that does not require that the gold be washed. Because of the extreme cold, the gold can only be mined about four months of the year and only at midday when the sun is overhead to provide light and some warmth.

This is the best documentation and shows why Pizarro had such intense interest in the gold mines in the region. He also saw samples of gold ore that had been brought back by the exploration team. Sancho continued,

> The Spaniards took from these lands a load of ore which was to be washed in front of the Governor, however, beforehand they swore that this was the same ore that was also used by the natives and from which three measures of gold were taken. They all knew of the mines, mining gold, and other ways to obtain the riches of the earth. They said that all of that territory had potential for gold. And, if the Spaniards were to give tools to the natives they could mine much more gold, and in less than a year, millions of ounces of gold could be had.

Sancho de la Hoz' description of the exploration carried out by the two Spaniards, Diego de Aguero and Pedro Martinez de Moguer, in the Collao region, is especially important to ancient mining history of Perú. It is understood to be the oldest document that describes, first-hand, gold mining during Inca time. This report details the technical aspect of gold recovery and the rigors endured by the miners under Inca laws which were in place for only a short time before the new kings, the Spanish explorers, radically changed the laws and work ethic. This was a special report, a first-person report, and later writers who were concerned with, and who wrote about mining in ancient Perú, could only repeat hearsay or secondhand information.

Sancho, in his writings, omitted the exact dates of the 40 day exploration of the region. However, it can be deduced that it took place sometime between 15 November 1533 and 15 March 1534. Sancho indicates that the rivers were shallow which is characteristic of Altiplano rivers in December to January or until the beginning of the rainy season in the mountains. Rain may be common in the higher elevations of Jauja and other higher elevations in Collao. This meteorological note suggests the possibility that the trip took place during those months and it was also important that the explorers returned before the "Reparto de Cusco" which was a celebration that took place in the beginning of March 1534 or essentially at the end of the Conquest. A few days later, on 15 March of the same year, "the very noble and great city of Cusco" was founded. After having organized the administrative details of gold mining for the Spanish king, Pizarro began the return march to Jauja, crossing the Rio Bilcas, today called Pampas, on Easter 1534.

Aguero and Martinez had found the great lake about which Cieza had said "…in the great basin of this province is a lake that is much wider and longer than any other in the land of the Indians,[17] and nearby are the villages of Collao, of which, Chuchiabo is the most important population center." The two Spaniards called it Lake Chuchiabo, a Spanish version of *Chuquiabo* or *Chuquiyapu*, an Aymara word, descriptive of the monotony and melancholy of the Altiplano whose borders vanished in the transparent air of the surrounding mountains and where, during the eons of geologic time, the "lagrimas del Sol" [gold nuggets and flakes] were copiously shed to crystallize as the rich gold deposits of Ananea, Carabaya, Chucuito, Chuquiyapu, Illimani, Puno, Sandia, and many others.

Sancho's descriptions indicated that the two explorers had visited the extreme southeast of Lago Chuchiabo, however, the rich mines of the Collao region were still some distance from the lake and there was still another mine further on from these. This geographic reference point is somewhat vague because there are two mountain ranges at Cordillera Apolobamba near Ananea, and also two near Lago Chuchiabo with Nevado Illimani (also known as Cordillera Real). These ranges are southwest oriented, have widespread alluvial gold deposits that, in the first example are 80 km, and in the second example are 140 km, from Lago Chuchiabo. There are questions as to whether the explorers actually visited the exact site of the mining district of *Chuquiyapu* that the Incas had described at Lago Chuchiabo. The reconnaissance done by Aguero and Martinez de Moguer gives two alternative routes: (1) the first, Cusco-Chucuito-Extremo southeast of Lago Chuchiabo is about 520 km and the route from the lake to the Cordillera Apolobamba is about 120 km or a total of approximately 650 km; (2) the second is Cusco-Chucuito-Chuchiabo and is approximately 630 km, the route from Chuchiabo to the Cordillera Real is about 50 km, or a total distance of approximately 680 km.

The two leaders, without having encountered any detours from a direct route, would have traveled 700 km from Cusco, and therefore a round trip of approximately 1400 km. The average daily travel might be 35 km during the 40 day trip, however, stops to describe and write, sampling, transport of supplies, and the fact that all other members of the party were on foot must be considered.

The focus of Aguero and Martinez was mainly on the gold mines and their descriptions included underground mining as well as alluvial mining. It seems that the geologic conditions and underground mining descriptions were from Prov. Sandia (Dept. Puno), which has been known for more than 40 years. The geology and mining discussion for the second type of mining were likely from Chucuiabo and Vilaque and are similar to descriptions from earlier visits.

In contrast to what is known of other regions such as Hualgayoc-Micuipampa and Cerro Descuelga-Illimani, the Spaniards found adits from 17 to 70 m in length, where the miners worked, unbelievably, without any direct light. This was a characteristic of these adits as well as being narrow and cramped, thereby permitting access for only one person. These types of workings were found only in detrital deposits such as gold placers and those deposited by glaciofluvial action. In Prov. Sandia (Dept. Puno), there are ancient workings, for example, at Llenqueni (Rio Tambopata) exactly as seen and described by Aguero and Martinez during their reconnaissance (Fig. 4). The adit is perhaps 1 m in height and the lower part is composed of loose rocks and rubble which are immediately above the underlying slate. It is at this contact where the gold is concentrated (Petersen, 1932). In this type of fluvioglacial conglomerate, very little framing of the adit is needed.

The moraines and other fluvioglacial deposits at the western base of Nevado Ananea also have excellent examples of mines that are more like wells and are about as deep as the height of a man. The detrital material contains irregularly distributed gold from the surface to the basal rocks. To successfully mine these deposits at an industrial scale, the subsurface units must be described by hand-sampling in the shallow pits which are similar to those workings described by Sancho. The mined material must then be washed manually in order to separate the gold.

In the vicinity of the hills, for example at Pampa Blanca, Anccocala, Huajchani, and others, water has to be brought from far away using small irrigation canals to wash the gold from the richer deposits and then concentrate the gold using flat rocks or large stones as riffles. The final separation of gold from the heavy minerals was done with a *batea*. Therefore, 400 years after the Inca, the inhabitants of the small towns and villages in the region still follow the ancient mining practices in order to make a living (Fig. 5).

It seems that Aguero and Martinez limited their reconnaissance of the alluvial gold deposits and did not attempt to climb the peaks described as "very high and exceptionally cold" to document the gold-bearing veins which were also mined by the local miners. The gold-bearing veins, wherever they cropped out, were typically found at the upper elevations in the mountain ranges that had been cut by running water. In the Bolivian, as well as in the Peruvian part of the Altiplano, ancient mine workings were found, with few exceptions, at more than 4500 m. For example, ancient adits were found at 5000 m at Cerro Descuelga (Illimani), at 4600 m at Anccocala, at 4750 m at Poto-Ananea, at 4800 m at Pampa Blanca, at 4900 m at Condoriquiña, and at more than 5000 m at La Rinconada de San Francisco. The mining towns are in desolate zones that are cold and have only sparse vegetation with the exception of a local grass known in Quechua as *ichu* or mountain straw.

The mining districts of the Altiplano and surrounding areas in ancient times were not well populated because of the difficult weather conditions. The people had to look for work in places with more agreeable climate. Those who worked under the strict orders of the owners and managers of the mines had to work in shifts of four months and their workday was generally from midday until sunset. This schedule was necessary because of the availability of water which was required to wash the gravels. During Inca times, gold mining was done on a grand scale using a system of canals to concentrate the gold. It was important to take advantage of a man's workday so that a large volume of material could be moved. Depending on the consolidation of the gold-bearing gravels, it usually required 40 m^3 of water to treat 1 m^3 of material to achieve the maximum gold concentration. Recovery was usually better from the deposits located at the base of the mountains. The work required large-scale hydraulic projects to divert the water from the local streams and also obtain meltwater from the glaciers on a daily basis. The amount of meltwater varied depending on the season as well as the position of the sun and generally, after 10 in the morning, there was sufficient water for gold washing. Melting typically slowed around 3 p.m. However, the water that had accumulated in the canals continued running for several hours, thereby permitting work to go on until nightfall.[18]

Since climate was so important, the best time for gold working in the Altiplano was usually during the rainy season. During the rest of the year, during the dry and cold seasons, the water almost dried up and precipitation consisted mainly of snow and ice. The few hours of sun followed by the cold were not sufficient to cause melting and most of the recent snowfall quickly evaporated into the thin atmosphere typical of high altitude. It is at this time that the miners would leave their secluded existence and return to their towns to farm and work their fields which were typically at elevations less than 4000 m.

The work regimen at the mines in the first years after the Conquest continued much the same as before. The mine managers continued their daily collection of gold for the chief from the collective work of the miners. This gold was then safeguarded so that no one could rob them of their hard won gold and the gates to the city were carefully watched and guarded. Aguero and Martinez' report brought up interesting aspects of the mining economy and sociology. For example, the everyday person appreciated copper for its use in tools and utensils, however, gold was different and its use was only for religious ceremonies and the elite.

They did not use gold for commerce or as money, instead goods and spices were bartered. The Spanish explorers said that the inhabitants of Collao traded with people of the coast as well as those who lived on the western slopes of the Andes and those who lived in the jungle, which was much lower. They also observed that the Inca chiefs were obliged to maintain strict control against theft of the gold. What, then, was the purpose of the gold? To sustain the family or cultivate the land? Was it used for payment? Gold was little used in trade with others, especially those in the jungle where gold was available and could be mined clandestinely without being watched by the Inca. Why was physical gold used for coastal trade if it were illicit to have or enjoy the gold?

For centuries there has been the idea of an ideal socialist state in which the paternal hand, in this case the Inca, gave to everyone according to their needs. This utopian image is very different than the reality preserved in the documents. In the Inca kingdom the regimen was efficient in all ways. There were contrasts such as between rich and poor, weak and strong, as well as those with political aspirations. There were those who sought personal gain and the best way to these ends was with gold. If the miner who worked the mines hoped to gain by robbing another to provide for himself, it was as serious an offense as using gold in a commercial transaction. These details suggest that it was an economic situation in which even use of the word could be construed as a black market with intent to provide contraband gold to the regions that were not under Inca rule, such as Colombia.

ETYMOLOGY OF TITICACA

Titicaca refers specifically to the island in the lake and was only later applied to Lago Collao. According to Villar (1887), *Wira*, *Huira*, or *Uira* are other ancient names also used for Lake Titicaca:

Umasuyo is the ancient name of the Lake Titicaca region (Posnansky, 1957).

Collao is the name used by Atahualpa during his captivity in Catamarca in 1532, "…in the region of Collao is a large lake in which there is an island" (Anónimo de Sevilla, p. 1938, p. 327), however, it is unlikely that Atahualpa actually saw the lake and what he described to the Spaniards was from hearsay.

Chuquiabo or *Chuquiyapu* referred to the great lake of Collao and was described in the 1534 Diego and Martinez expedition (Sancho, 1534). In Aymara, *choqque*, gold and *yapu*, property, mine or estate. Also, *Chuquiapo*, from *chuqui*, gold, and *apo*, divine one (Martín de Morúa, 1925).

Titicaca was used by Cieza de León (1553) who traveled in Collao in 1549 and said that the name was taken from a temple that was at the lake. It seems that Titicaca is a recent name of the lake, however, there are other Aymara names such as *tartap-tatta cota*, the lake formed by the union of the waters, and according to Belisario Cano, the Lake of Cataclysm; also *taripkota*, *taripay* which indicated a meeting (Middendorf, 1890); also Lake of Universal Judgment (Cano, s.a.) from *tariy*, to find that for which you search (Lira, 1945).

The name of the island comes from:

Chaya, or *Challa*, or *Tichicasa*, the name of a village on the island (Stiglich, 1922). Aguero and Martinez described a religious site with a stone that was used for sacrifice that was called *Tichicasa* (Sancho, 1534).

Titicaca was the term used for the island and the lake by Cieza de León who traveled in the region some 15 years after Aguero and Martinez.

Cano (s.a., p. 147) referred to *Aymartaru* and *Sol* and said that there exists a sacred stone hill where there was a cat made of stone. Others attributed the name to *Con-Tecsi-Viracocha* or one who could predict and tell the future. This stone was called *ititcalo* or the stone cat (Manuel V. Vallivián, oral commun., 1968). Also, *tecca-kaka* or rock foundation. Garcilaso de la Vega used the word, *Titicaca*, meaning stone or mountain of lead and, and according to Belisario Cano (1968, oral commun.) *tecsi caca* meant the basis or foundation of your beliefs.

Quechua Etymology

The Quecha derivation of the word includes *titi* or *tite*, meaning lead and *caca*, foundation, rock, or lead mountain (Santo Tomás, 1560, Garcilaso de la Vega, 1609); *kacca*, foundation (Gonzáles Holguín, 1608); *titi*, lead and *kaka*, a foundation or rocky area (Middendorf, 1890); *titi*, lead, a solid foundation (Lira, 1945); *titi*, lead, copper, or a jungle monkey, a rock containing lead (Perroud and Chouvenc (1970). Squier (1878) and Middendorf (1895) explored the island in Lake Titicaca and concluded that there was no lead mineralization from which the name could have been derived. The rocks of the island were red, and not even lead-gray as the name would suggest. Field studies by Cabrera La Rosa and Petersen (1936) and Newell (1949) confirmed the earlier observations.

From a mining and metallurgical point of view, the word "lead" was used in the Moche and Yunga language since A.D. 200–300. In the latest compilation of the Yunga language (Zevallos Quiñones, 1947), a word for "lead" does not appear. Apparently, the word "lead" appeared in the Altiplano, because of the mining and metallurgy of the region, around A.D. 1300, however, this is much later than the use of the word *titi* which is much older and apparently is not related to the metal lead.

Therefore, the use of the word *titi* seems to have been an Andean geographic concept and not a reference to lead. The term was widely used in the geographic references of Paz Soldán (1877), Stiglich (1922), and in the Carta Nacional (1:200,000):

Titi	name of a hill, Prov. Canta
Titiaquí	town, Dist. Huata, Prov. Carabaya
Titicaca	lake, Dept. Puno
Titicaca	ranch, Limatambo, Prov. Anta, Dept. Cusco
Titicache	area south of the mouth of the Rio Ilave
Titicachi	area near Chucuito, Dept. Puno
Titicasa	hill with cinnabar veins, Dist. Santa Barbara, Dept. Huancavelica
Titicasa	hill, Dist. Tambo, Prov. La Mar
Titicasa	town, Dist. Huancaña, Prov. Lucanas
Titicasa	town, Prov. Yungay
Titicocha	lake at the base of a snow-capped mountain, Prov. Huarochiri, Dept. Lima
Titicota	town, Dist. Oyon, Prov. Cajatambo, Dept. Ancash
Tithui	ranch, Prov. Huacane
Titijahuana	pampa, Prov. Tarata
Titijones	stream and ranch, 30 km NE of Torata, Dept. Moquegua
Titilaca	Dist. Chucuito, Dept. Puno
Titimina	hill with coal, Prov. Yauli, Dept. Junin
Titimina	lead, Dist. Laraos, Prov. Yauyos
Titimina	hill with copper and silver, Prov. Huancayo
Titini Yavira	stream, tributary of Rio Ninantaya
Titirana	hill with gold, Prov. Carabaya
Titiri	town, Dist. Santiago, Prov. Azangáro, Dept. Puno
Titisalli	town, Dist. Achaya, Prov. Azangáro, Dept. Puno.

These place names were used in a vast region that was first inhabited by the Aymara and later by the Quechua (Tschopik, 1946). *Titi* is either used alone or in compound form with the words for coal, cinnabar, hill, town or village, plain, snow-capped, copper, silver, gold, or lead mines as well as with stream, village, or huts.

Aymara Etymology

The place name *Titicala* (*Titicaca*) may also be related to Aymara words such as *titi*, wildcat and *cala*, *qala* or stone: Peña de Gato (Torres Rubio, 1616); Diccionario Hispánico Universal; *titi*, tiger, Pena del Tigre (Squier, 1878). It is thought that there was a group of rough foundations that from a distance look much like a tiger. However, Middendorf (1895) while in the supposed location was not able to distinguish the feature. Among the features described by Squier (1878) was one called *Pumapunco*, or Portal of the Puma.[19] According to Valcárcel (1932, p. 7), the pronunciation of *titi*, lead or tin, is distinct from *titi*, wildcat, and sounds more like *tete* when referring to the metal. Bandelier (1966, oral commun.) considers that the actual name of Lake Titicaca may have been changed from a primitive word *Titikala*, which is Aymara for Piedra de Gato, or place of the wildcats.

Such cats, to the ancient Aymara, were a constant theme (Tello, 1923). However, in the case of Titicaca, this usage does not refer to the wildcat (**Oncifelis geoffroyi**) that lives at lower elevations east of the Andes, nor the Andean wildcat (**Orcaiturus jaboita**) whose habitat is mainly in the southern Altiplano. As a solution to the etymological problem, Valcárcel (1932) suggests that the name is from *titi*, Gato de Agua or Gato de Rio (a type of nutria, **Lutra sp.**) common in the Rio Mayupuma and which has been found on Isla Titicaca, whereas, no wildcats or pumas have been sighted on the island. He also cites pictorial and sculptural references found in Nazca, Pucará, and Tiahuanaco art as well as papers on the mythology of the Andes. Betanzos (1551), in *Suma y Narración de los Incas* [*Summary and Narration of the Incas*], wrote the word *titi*, which after editing, was intentionally changed to *tejsi* which was criticized by Bandelier (oral commun., 1966) and Valcárcel (1932, p. 137). They concluded that those earlier writings had changed the original Andean meaning of the words in order to express metaphysical concepts. And, in this case, the change from *titi* to *tejsi* was done in order to introduce a metaphysical concept of beginnings and origins. This observation is important in light of the etymological explanations of Lago Titicaca discussed by Cano (1933).

The indigenous tribes captured and domesticated, to a certain extent, the puma or mountain lion (**Puma concolor**), the jaguar (**Panthera onca**), as well as other cats and kept them in special cages as indicated by the words *pumacurco*, *pumatampo*, and *pumata*. The relation between the jaguar and the moon in the mythology of the Andes is described by Kunike (1923) who includes ancient ceramics as evidence. Along the same lines, Lanning (1967) discusses the feline deities of the Early Horizon that also appear in Tiahuanaco as a continuation from the Chavin culture from the coast to the Altiplano.

After their conquest of Collao, the Incas from Cusco, constructed their own temples on the religious sites of the Collas on Isla Titicaca, thereby replacing the religion of the Moon with the religion of the Sun. Their thoughts were to weld their religion and divine origin with the religious themes of the ancient Aymara. This was shown in many of the temples in the region.[20] In the complex myths and legends of the Aymara, there are references to the Titicaca region as the unifier of the skies and earth and creator of the world. The many concepts were studied by scholars who also included discussion of a tall man dressed in white coming from Lago Collasuyo who accomplished miracles on the island and at Titicaca and whose throne was at Tiahuanaco. His name, *Huiracocha*, *Wiracocha*, *Con Titi Wiracocha* is usually accompanied by prefixes suggesting to the authors that *Wiracocha* is not Quechua or Aymara origin but is from a much older language.

Therefore, these interpretations, from a mining point of view, of the names of the island and of Lake Titicaca and use of the word *titi* to infer lead (Quechua) or a cat (Aymara) are both doubtful. Possibly, *titi* is Quechua, and the word Titicaca is modern usage. The words, *wira*, *huira*, or *titi* may also be the same age and use as *wira,* as a prefix, for example, in the name *Huiracocha*. Indeed, there is no satisfactory explanation and it is possible that the word belongs to a language that has now disappeared (Trimborn, 1961).

Since linguistic and mythological studies of ancient Perú have not resolved the etymology of Titicaca, we are essentially at the same point that we have been for more than four centuries, since the time of Aguero and Martinez, who described the wonder of Lago Chuchiabo, or Chuquiyapu, as the "great lake that washes golden shores."

CHAPTER 7

Metallurgy

GOLD

The most ancient metallurgical processing sites for gold in ancient Perú are from the Early Horizon (900 B.C. to A.D. 200). Gold was only worked in its native state and there is no evidence that any complex gold compounds were worked. When gold and silver alloys were found together as electrum, the metal was worked in this state without any further refining or parting.

SILVER

Native silver may be found in outcrop and also in the oxidation zone of silver-bearing veins and can also be obtained by firesetting. The heat from this process is sufficient to cause the silver to melt according to Jerez (1534), Alonso Barba (1640), and Humboldt (1829).

Silver may also be obtained from silver-bearing galena and cerargyrite at Huantajaya and Yabrico (Solari, 1967). Argentite and other silver sulfides may be used and treated in shallow pits or in the *huayras*, which are meter-sized, tower-like furnaces. The first of these methods consists of pits in the ground commonly at the foot of the hills. Their form, as well as separation of silver from galena was described by Alonso Barba (1640). For fuel, wood was used (*yenta cheqta*, wood; *chejta*, wood chips) as well as grass, dry straw or *ichu* (**Stipa jaraba**); *taquia*, dried animal dung; *yarita*, a high-altitude, pillow-like ground plant (**Azorella yarita**) as well as a moss (**Distichia muscoides**).

In the second method, *huayras* were used to smelt the silver-bearing ores. According to the descriptions given by Cieza de León (1553, 1924 edition, p. 309), Zárate (1555), Alonso Barba (1640), and Bargalló (1955), these furnaces were originally used in one place, however, were later transported. These are smelting furnaces that are driven by the wind that ascends the hills during certain hours of the day and night and are variously called *braceros* (Cobo, 1653/1956), *huayras, guairas*, or *huaris* (from Quechua, meaning air or wind) by ancient Peruvians. The parting of the silver was done in a *tocochimbo*, *tocochimpo*, or *ttocoychimpu* (from Quechua, a basket full of holes to toast corn) (González Holguín, 1068/1952); *t'okko*, hole, *t'okkochay*, to deepen or hollow (Fig. 10: 1, 3, and 4). This was a type of metallurgical muffle furnace used to smelt a small volume of rich ore. During Inca time, it was used to refine the silver (Alonso Barba, 1640, p. 133; Bargalló, 1955).

The varied forms of the smelters can be grouped into three basic styles:

1. Smelters of loose stones, not very high, with no clay mortar so that the wind could easily pass through.
2. Stone and mortar smelters, with or without clay plaster, and with openings for the circulation of air, generally circular, for example, see Ahlfeld and Schneider-Scherbina (1964, Fig. 114) which is an ancient silver smelter from Quioma, Bolivia, in which silver was smelted from cerargyrite, argentite, and silver-bearing galena. The ancient name, *huairachina* (from Quechua, *huaira*, air, wind; *huairachiy*, to blow the fire or coals; *wayra*, air; *wayrachina*, special oven for smelting silver) (Ricardo, 1586; Aguilar, 1970).
3. Portable clay smelters, rounded or square base, inverted truncated cone or pyramid-shaped, height of 80–90 cm, width of 40 cm in the upper part. The walls have holes for air, either natural or for use with tuyeres. Commonly with a plate-like base and a pan-like area for the smelted metal (*llaska*, smelted metal) and smelter scoria (*qquellaypa acan*, González Holguín, 1568) to collect. During smelting, coals are kept in the pan to preheat and circulate the air. The quantity of metal obtained from each smelt was small and some metal was also volatized. Fuel included wood and charcoal (*qquillimsa*, *k'illinsa*, or *k'illima*, charcoal) (Middendorf, 1890); *k'illimsay*, to make charcoal, carbon (Lira, 1945). These are shown in Alonso Barba (1640/1947), Bargalló (1955, 1967), and Helmer (1962, figs. 3 and 10.2).

Cieza de Leon (1553/1924, p. 309), in Chapter CIX of his travels in the Altiplano in 1549, gives his observations on silver smelting:

> At Potosí, it appears that the metal is not smelted using bellows but rather the ore is put directly into the fiery coals to be converted to silver. At Porco, and perhaps other parts of this ancient kingdom where metals are smelted, there are many ingots of silver showing that the metal is purified and separated from the smelter scoria using fire and bellows. However, at Potosí, where there is also much silver, the bellows cannot be used.
>
> This is because of the type of ore minerals at Potosí or perhaps for some other unknown reason. Metalsmiths at Potosí have tried to obtain silver by using the Spanish bellows and have gotten nothing for their work, which is unusual given that the bellows are an ancient and reliable smelting tool. In ancient times, the Incas were very wise in their smelting techniques of silver and did not want it to flow using bellows.
>
> Instead, at Potosí, they smelted the metal in clay pots that looked much like Spanish flowerpots, complete with holes for the evening wind or to be used for *tuyeres*. In these pots were placed charcoal, with the ore on top, and then these smelters were fired on the slopes and hills where the wind was more forceful and released the silver, which

was later purified using small bellows or *tuyeres*. In this way, much silver was taken from Potosí.

And then, the ancient miners returned again to Potosí, the great round mountain, for more silver ore. These smelters were called *huayras* (*guairas*) and by night they were so abundant in the surrounding hillsides that they looked like *luminarias*. The evening breeze helped to increase the amount of silver that was produced. There was really no other way used to produce silver, and, just as the wind is necessary to sail the oceans, the wind is equally necessary for smelting silver.

There were no silver merchants from whom they could obtain the metal, therefore, they only had to go to the mountains which had been blessed with the precious metal, smelt it, and return to their villages with great quantities of silver. It is for this reason that miners and craftsmen from many parts of the Inca world were drawn to Potosí to take advantage of such great mineral wealth.

In Chapter XXVII of volume I of Los Comentarios Reales de Garcilaso de la Vega (1609, 1941 edition, p. 203) other details on smelting are given:

Smelting is done with copper-tipped *tuyeres* or blow-tubes that may be more or less an arm's length regardless of whether or not the quantity of material to be refined is large or small. The *tuyeres* have a restriction which leaves a small orifice through which the air comes with more force, although somewhat slower. It is customary that from eight to twelve people gather around the smelter to blow with their *tuyeres*. Since there are no crucibles, likewise there are no tongs to take the metal from the fire. Instead, the metal is drained using wood or copper tools so that the metal goes immediately into a damp mound of earth and then can be further refined. The metal is moved from one to the other until it cools and can be handled. With these simple tools marvelous art pieces can be made. Even given the simplicity of the smelting methods, caution is important because the fumes from any metal are dangerous, therefore, smelting is done in the open and not in a covered area.

Bargalló (1967, p. 43–47) compiled information on smelting from many authors and concluded that smelter types 1 and 2 were used by the ancient Andeans and type 3 was Spanish-influenced. The modifications noted on type 3 suggest that this style may have been little used by the ancient metallurgists. It is known that this style was widely manufactured at the beginning of the Colonial period and literally thousands were made to satisfy the demands of Colonial silver trade. Bargalló's writings and bibliography are a wealth of information and he argues that it is difficult to be certain whether the *huarya* (or *guaira*) is an Inca or Colonial device mainly because Colonial mining has been superimposed on, and mixed with, artifacts at many Inca mining sites. This is evident at Porco and Loa. Only *huayra* fragments from a site not occupied by the Spanish can undoubtedly prove the ancient origin and use of the *huayra*.

Latcham (1936, p. 107) discusses metallurgy in the regions inhabited by the Diaguitas and the Atacameños (tribes of Chile and northwestern Argentina, respectively, approximately A.D. 500–600) and tries to resolve the question of the use of the portable clay smelters by ancient people and acknowledges that both the ancient Andeans and the Spanish understood metallurgy. Metal artifacts of the same style were found in Bolivia and later in southern Perú, however, apart from these regions, similar metal objects were not found. In Argentina and Chile, mines have been found that were worked during ancient time, and nearby, were found *huayras* and smelters used by ancient miners as well as crucibles and used clay molds. Therefore, the use of the portable smelters and the knowledge that changing the location of the smelter on the hillside to allow the smelters to better take advantage of the winds was known before the arrival of the Europeans.

The silver-bearing lead that was obtained from the *huayras* was refined using silver in special ovens that were round, about 80 cm in diameter, with two openings, the smaller one was for air, and in front, a larger hole that was a half-cylinder in which the charge was placed. Between the charge and the wall of the oven was a space of 15 cm that was filled with charcoal placed through a hole in the upper part of the oven which was later closed with a cover of baked clay (Jiménez, 1924, p. 14). If necessary, refining silver usually took one or more operations. To increase the heat from the charcoal, the ancient metallurgists used *tuyeres* of copper, reed, or cane. The pure silver was caught in small, hollow, clay or stone molds.

The silver minerals to be smelted were mixed with galena or *suruchec* so that the metal would flow more easily, however, this was a carefully watched procedure because air was gradually and carefully introduced in order to conserve the charcoal and not vaporize the metal. Whereas, on the other hand, if the wind were very weak, smelting could not take place. Smelting took place in ancient Perú using *huayras* that were either fixed or portable and there were other elaborate metallurgical sites with larger ovens such as those found at Curamba, Urcón (Pallasca), and Cerro de Pasco.

Curamba Smelter

The Curamba (also Corumba, Curampa) smelter ruins are approximately 28 km west of Abancay and 6 km from Huancarama, Prov. Andahuylas, Dept. Apurimac at an altitude of 3710 m and were described by Garcilaso de la Vega (P.I., 1. IV, p. 340). Wiener (1880, p. 278), in another reference, gives a map of the site, however, the location of the smelter, which he considers to have been constructed by the Spanish or Portuguese and does not give evidence or a specific reason, is not very precise. Descriptions by Olaechea (1901) agree with Ing. Darío Valdizán, who explored the site in 1888 and gives a detailed description of the metallurgical facilities on two maps. The ovens were on three artificial embankments that were approximately 5 m wide and 1.6 m high and were thought to have been originally constructed during the Inca period. There are more than 40 individual ovens grouped by threes. The ovens have a depth of approximately 3 m and are approximately 50 cm in height and the floor is gently inclined. A short distance away are seven collapsed mine workings.

The positioning of the furnaces in threes is to accommodate the smelting of the minerals and Olaechea considers that the first and second steps were done in the external ovens and the refining was done in the central chamber.

In Urcón (Prov. Pallasca, Dept. Ancash; R.R., 1894, p. 7;), approximately 4 leagues from Corongo, the capital of the province, are the ancient ruins of a smelter similar to those described above (J. Torrico y Mesa). This site dates to Inca time and had a very rich mine which is now sealed with a large rock (Olaechea, 1901).

MERCURY

Huancavelica is the only place in Perú that has any indications of ancient production and smelting of cinnabar. Small amounts of native mercury can be obtained by washing the sand in the local streams and could have been used for metalwork without further treatment. There are no clear references that indicate that cinnabar, the main ore of mercury, was smelted in ancient time to obtain metallic mercury. Instead, pure cinnabar appears to have been made by a metallurgical process, and according to Gastelumendi (1921, p. 42):

During Inca time, cinnabar or *llimpi* from Huancavelica was well-known to ancient Peruvians and was used as paint. Among the ancient Andeans, it was commonly used as a cosmetic to color the skin. A tradition that I had the opportunity to verify by having seen it, included a special tube of baked clay, in a cylindrical form, open at one end and closed at the other, and was told that this was one of the type used by the miners to extract *azogue* [mercury], with many tubes arranged in line on a channel that served as a burner, fired with straw, after which the mineral was put inside, heat-sealed along with the other tubes, in which the mercury condensed; having learned also that the slag was called *ponti*. Undoubtedly, this is what they did, but not to produce mercury, but only to sublimate the impure cinnabar to obtain a pure paint; now the vessel where the mineral had been placed was well-sealed and heated with no contact with the air, so as not to oxidize the cinnabar, but only cause sublimation of the cinnabar, thereby producing the desired paint, known as vermillion.

The ancient miners produced cinnabar by working the softer rocks, such as sandstone, by using tools made from harder material such as volcanic rocks. When used to mine cinnabar, limestone and conglomerate tools simply fell apart or were easily broken. Rocks from the mine were very hard and appeared to have been metamorphosed and stretched.

TIN

There are a number of references to pre-Columbian tin mining in Bolivia, where, as in Perú, outcrops of tin were found in many places. For the production of bronze, metallic tin was needed and artifacts found at archaeological sites are evidence that the ancient metallurgists knew how to smelt tin from its ores.

In copper smelting, occasionally tin may be present from stannite as a minor component, however, to produce metallic tin in any quantity, cassiterite must be used. Smelting tin is a relatively easy process which would not have been difficult for the ancient metallurgists. Cassiterite, after separation, was mixed with charcoal fragments, sand, and limestone in order to produce a more fluid slag. This mixture helped maintain the temperature so that a liquid metal could accumulate in the base of the smelter. If the cassiterite contained impurities such as Fe or SiO_2, then higher temperatures would have been required for smelting. This was a delicate process as temperatures that were too high would have resulted in volatization of the tin and absorption of the slag.

COPPER

Native copper was found associated with igneous rocks and their volcanic emissions and in zones of enrichment above magmatic copper deposits, also known as porphyry copper deposits. Weathering of these porphyry copper deposits results in supergene enrichment, described in Chapter 1. With respect to the use of copper in Bolivia in ancient times, Ahlfeld and Schneider-Scherbina (1964) describe the importance of copper originating from Tertiary volcanism, and give as examples, Corocoro, Turco, and other Bolivian mines that provided metal used to produce idols made of copper-tin alloys. An ancient bronze smelter from Yanamayo has been included in the Buck Collection in La Paz, Bolivia.

Native copper or copper obtained from metallurgy is rarely pure and the impurities are related to the geochemical character of the deposit. The Cerro de Pasco Corporation provided sample descriptions and spectrographic analyses of samples of native copper (Table 7) from four occurrences:

1. Mina Cerro de Pasco, native copper on display at the Museo de Geología of the Universidad Nacional de Ingeniería; also see Chapter 3 and Figure 6.

TABLE 7. QUALITATIVE ANALYSES OF NATIVE COPPER FROM PERU

	Cerro de Pasco	Yauricocha	Cobriza	Raúl
Ag	V	W	W	V
Al	W	W	W	V
As	x	V	V	x
B	W	V	V	V
Ba	x	V	V	x
Bi	V	V	x	x
Ca	W	x	x	x
Cr	W	W	W	x
Cu	M	M	M	M
Fe	m	m	S	S
Hg	x	x	x	V
In	x	V	V	x
Mg	V	V	V	V
Mn	S	W	V	V
Mo	V	W	V	V
Na	x	x	x	V
Ni	V	x	V	V
P	x	V	V	x
Pb	V	V	W	V
Pd	W	W	W	x
Sb	x	V	V	x
Si	m	m	m	W
Sn	x	V	V	x
V	W	V	V	x
Zn	W	W	V	V

Note: Key: M = >10%; m = 1.0–10%; S = 0.1–1.0%; W = 0.01–0.1%; V = < 0.01%; x = investigated but not detected

2. Mina Yauricocha, Prov. Yauyos, copper fragment from the collection of the Departamento de Geología, Cerro de Pasco Corp., La Oroya.
3. Mina Cobriza, Rio Mantaro, fragment of native copper from the collection of the Departamento de Geología, Cerro de Pasco Corp., La Oroya.
4. Mina Raúl, 5 km southeast of Mala, Dept. Lima, Companía Minera Pativilca S.A. and Mauricio Hochschild y Cía. S.A., fragments of native copper 2–3 cm in length. (CP)

The qualitative analyses of samples from Cerro de Pasco (1) and Raúl (4) are from the Laboratorio de Dosimasia, Universidad Nacional de Ingeniería. Native copper samples from Cerro de Pasco (1) and Raúl (4) were also analyzed in the Laborátorio de Analisis Quimico Inorgánico (Cert. no. 25873, 31 December 1970, by Sra. M. Macedo de Rojas) with the following results:

	SiO_2	Cu	Fe	Au	Total
Cerro de Pasco	1.42	98.56	0.001	0.00081	99.98%
Mina Raúl	2.30	97.64	0.05	—	99.99%

Qualitative Analysis of Native Copper from Perú

Impurities in copper may range from very low to trace amounts. With native copper, the trace elements are included in the copper matrix and therefore, also in the copper artifacts (Tables 9, 10, and 11). Indium, palladium, and other platinum group elements, as well as arsenic and silicon, may also be included. The samples from Cerro de Pasco, Yauricocha, and Cobriza also include arsenic minerals. The absence of arsenic in native copper from the Cerro de Pasco sample may be explained by the absence of arsenic minerals, such as enargite, from the ore. This is especially important in sourcing artifact copper to the copper occurrence. The presence of platinum group elements in gold-silver artifacts is likely due to the copper that is a common constituent of the alloy (Table 17). The presence of nickel in copper samples from Cerro de Pasco, Cobriza, and Raúl is significant because it seems to be a common impurity in Peruvian ores and was initially discussed by Caley (1970).

Both native copper, as well as smelted copper, tend to have impurities and can still be used directly in fabricating tools and other objects and is ideal for laminations as well as cold-working. For casting, however, the copper may be porous and may absorb hydrogen, CO_2, and sulfur which may be released upon cooling. It is also difficult to obtain a homogenous melt.[21]

In Perú, native copper was especially useful and a readily available industrial metal for the ancient miner. This is in contrast to copper occurrences, commonly of volcanic origin, in Bolivia and other countries. Therefore, it is unclear whether or not the ancient Peruvians worked native copper from other regions. If the ancient metallurgist needed large amounts of copper, it may have been obtained from the Altiplano of Bolivia or Chile. This problem is difficult to resolve and it seems likely that they worked with copper that they had smelted or, secondarily, copper that was imported by trade.

The Chilean mines of Loa, Atacama, and Chuquicamata, where native copper, chlorides of copper, and carbonates of copper are found, may have also been worked in ancient time (Bargalló, 1955; Solari, 1967). The opinion that all the copper used in ancient Perú was sourced from the north of Chile is not substantiated and there is sufficient evidence of mining and copper smelting at several sites in Bolivia and Perú. These include metal sites at Chan Chan, near Trujillo; the nearby site of Batán Grande, Lambayaque; in the Moche region, northern Perú, where between ~A.D. 200 and 1000, copper was found in crucibles and as ingots for later use (Lanning, 1967).

The ovens and smelting devices used to produce copper were basically very similar to those used for silver processing, however, there exist references to copper that was smelted in pits in the ground or in crucibles in which the oxides were reduced using charcoal (Jiménez, 1924, p. 14). The reduction process used the gentler winter breezes or *tuyeres* of cane or copper; the bellows did not come into use until the end of the Inca period.

Typically the ancient Peruvian metallurgists preferred chrysocolla, azurite, or malachite, all of which were available in outcrops in the Andean or coastal regions. There is also evidence that chalcocite, covellite, and chalcopyrite were used. These came directly from vein occurrences and most likely from the weathering zone where transformation to oxides was not complete.

Treatment of these different types of ores required a simple metallurgical process. The ores, after having been separated from the waste, were crushed in a mortar.[22] The concentrate obtained from this mechanical separation was mixed with charcoal, which during combustion, combined with the oxygen of the ore, and resulted in a pure metal that could be separated from the slag by gravity. This process was begun at a temperature of approximately 500 °C and ended at about 1084 °C, the temperature at which the copper began to separate. The composition of the fluid slag depended on the addition of fluxes such as sand, calcium, or limestone, the quantity of which depended on the experience of the metallurgist.

In the case of sulfide ores, the process was more complicated and a process called roasting was used to eliminate the sulfur. Given the rudimentary technical facilities of the time, this procedure, as well as the actual smelting, was somewhat deficient technically. This explains the presence of sulfur in the final smelt as well as in the final manufactured product (Tables 9 and 10). Depending on the mineralogy of specific ore, this initial process of roasting was usually begun at ~300 °C. Care was taken so that the temperature did not rise too quickly so as to avoid the partial fusion of the charge which would have interrupted the roasting and caused retention of some of the sulfur. During this process, arsenic and antimony were also volatized. The elimination of iron contained in the ores, from chalcopyrite, caused serious problems because the iron could combine with the oxygen and produce a silicate slag. Toward the end of this intermediate process, a copper oxide was produced, which by using charcoal, was reduced to copper. Smelting tools and an ingot of copper are shown on Figure 11.

As an example of the smelting of sulfide ores, twenty-two copper ingots found by Sr. Pablo Soldi of Ica at the metallurgical center of La Legua, in the Rio Ingenio-Rio Grande Valley, were analyzed by Caley and Easby (1959):

Cu	97.77%
Fe	1.44%
Ni	0.01%
S	0.18%
	99.40%
Note: Trace Ag and Sn.	

A METALLURGICAL CENTER AT CHAN CHAN†

Chan Chan, near Trujillo, was a center of Chimú culture and has been studied in more detail. The region includes Lambayeque, Chiclayo, and Trujillo. In Moche, *Jang-Jang* or *Sol-Sol* (Middendorf, 1894); *Xllang* or *Xllangic* (Carrera, 1644); also *Cheang*; also *Shiam Jiam* (Zevallos Quiñones, 1947).

In his reconnaissance of Perú, Squier (1878, p. 141 and 164) interprets a large smelter at Chan Chan:

…referring to a sub-barrio, in one of the larger plazas…with a double row of structures on the north side, however, along the south wall is a sequence of which were possibly ancient ovens or smelters which are quite in disrepair so that it is impossible to interpret their initial construction or purpose. The thick walls have been deeply burned, are calcined, and fragments of the smelter scoria are stuck to them. There is a large open space nearby where there is a great amount of mineral material, which upon analysis, was found to be principally copper and silver ore. We have proof of the skills of the Chimú in metallurgy as indicated by the ornaments and other objects made of gold, silver, and bronze. We have other indications that the grand chambers were occupied by specialized artisans and the smallest chambers were used by the artisans who separated the metals from their ores and worked the metals into ornaments and other objects.

In only a few years we have seen that many of the walls of Chan Chan have collapsed and the clay-plaster on the walls has become mixed with the smelter scoria. The calcined clay has the same appearance as the scoria at the Toma Luz site which was discussed earlier.

The locations with smelter scoria are mainly in the Tschudi and Tello ciudadelas. Hollister (1955), who made a detailed study of the scoria (Table 8), came to the conclusion that the ores originally contained 0.5%–1.2% copper, however, may have had up to 10%–20% copper and 0.16%–0.84% sulfur, which shows that sulfide copper ores were processed. The smelter scoria contained 0.04% to 0.14 troy ounces of silver. The smelting ovens, which were made of refractory material, were covered with impure clay, which was partially calcined and mixed with the waste material. Based on the chemical composition and vessiculation of the scoria, it is estimated that temperatures were approximately 1300 °C, which is much higher than the 980 °C that is normal in modern smelters. Samples of the ore were not found and it is likely that the source of the ore was in the mountain ranges some 100 km east of Trujillo.

In a paper presented at a symposium at the Museum of Fine Arts (Boston, Massachusetts, USA) on the composition of ancient copper artifacts from South America, Caley (1970) indicated that even given the publication of some 600 analyses, the knowledge of the material was not satisfactory because the majority of the analyses were problematic. For example, 42% of those analyses were qualitative and 31% had been determinations on only one or two elements and important trace element data were not available. Also, the archaeological setting of the artifacts was unclear, and therefore, of little use for chronology.

To resolve these regional problems of chronology and mining history, Caley (1970) performed 11 new analyses on copper

†*Note:* The "scoria" at Tschudi has since been determined to be non-metallurgical. See Appendix, Selected Bibliography, Cremation and the Chan Chan Burned Site, Lechtman and Moseley (1975) and Brooks et al. (2008).

TABLE 8. ANALYSES OF ANCIENT AND MODERN SMELTER SCORIA[1]

	Chan Chan, Tschudi, depth	Chan Chan, Tschudi, surface	Chan Chan, Tello	Shorey smelter	Garfield smelter	Chan Chan, thesis	Chan Chan, thesis
Au (oz)	nd	nd	nd	tr	–	–	–
Ag (oz)	0.04	0.04	0.14	0.5	–	–	–
Cu	0.85	0.12	0.05	0.9	0.4	–	–
Pb/Zn	nd	Nd	nd	nd	–	–	–
S	0.16	0.22	0.84	0.58	–	–	–
SiO_2	59.44	57.40	59.42	29.18	38.5	65.0	53.2
Fe*	5.5	4.3	5.6	43.6	44.0	–	–
Fe_2O_3	–	–	–	–	–	10.0	22.5
Al_2O_3	16.98	17.9	17.2	4.92	6.0	12.5	14.5
CaO	4.3	4.6	4.7	0.7	10.0	1.5	1.1
MgO	–	–	–	–	–	1.0	1.1
K_2O/Na_2O	–	–	–	–	–	3.3	3.3

[1]Hollister (1955).
*Determined as FeO and Fe_3O_4, not as Fe.

artifacts such as lance points, ornaments, needles, a tumi, a rattle, a hatchet, instruments, and copper sheets. Five analyses were on objects from IV–VIII century sites, five were on VIII–XII century objects, three on X–XII century objects, and one on an object from a XII–XV century site. The results are presented below (Caley, 1970, tables VI and VII) (also see Table 10):

Cu	96.75%–99.86%	Sb	0%–0.30%
Ag	0%–0.83%	Bi	0.025%
Au	0%–1.21%	Fe	0.01%–0.08%
Sn	0%–1.26%	Ni	0%–2.68%
Pb	0%–0.18%	Co	0%–0.01%
As	0%–3.07%	S	0%–0.15%
Total	97.24%–100.04%		

In order to interpret Caley's analyses, it is important to note that the objects were made from native copper. The metal used for other artifacts was made from copper of varying purity, from a variety of ores, and possibly with different smelting techniques. Sulfur is present in five analyses and suggests that sulfide ores were smelted. Arsenic is another important component and tin has been found in four objects from Tantamayo, Batán Grande, Chan Chan, and Jauja. Silver, which is common in copper, was not present in the analyses. Nickel, which is also a common impurity, had been ignored until now. Caley indicated that previously, this element had not been included in the analyses. The high gold content of 1.21% of the sample from Chavin does not appear to be accidental and may be due to the inclusion of *tumbaga* (Cu-Au-Ag alloy) fragments.

The diverse geographic distribution and sources of the objects analyzed by Caley do not permit a discussion of regional chemical patterns. However, on the basis of analyses available for copper and bronze artifacts published by Bowman (written commun., 1966), Jijón y Camaaño (1922), Mead (1915), and others it can be deduced that pure copper artifacts may be found in the north of Argentina and Chile as well at Tiahuanaco (Early) and in an area including the northwest coast of Perú, Ecuador, and Colombia.

Jijón y Camaaño (1922), on the basis of previous work by Rivet and Arsandaux (1946), found that 23 of 158 copper objects from Ecuador contained tin. It is generally known that the harder copper objects were cold-hammered.

Analyses of farm tools from Chepén (Dist. Pacasmayo) indicated that of 51 copper objects, 10 contained tin (92.00%–99.62% copper; 0.15%–7.98% tin) and of the 41 remaining objects, six had trace amounts of iron, four had trace amounts of tin, and one had trace amounts of antimony (see Table 9).

Dr. Earle R. Caley, of the Ohio State University, Columbus, Ohio, analyzed three samples of copper tools from the ruins of the ancient fort at Tumbes (Table 10). He indicated that the analyses were obtained using gravimetric methods and the totals are low because of the presence of oxidized metal (written commun., 2 November 1970) (Table 11). Samples A and B contain copper oxides which could have originally been in the sample as a result of smelting and there is little indication of internal corrosion. On the other hand, sample C has intergranular corrosion throughout and it seems difficult to obtain samples without some signs of corrosion. Therefore, the analyses for samples A and B likely represent the composition of the metal in its original state and the analysis for sample C is less exact.

The presence of arsenic as an impurity in the three samples appears significant in light of previous analyses which indicate that this element may be found as a minor or major element in Peruvian copper. The probable source of the copper for samples A and B is likely the same and this is based on the fact that both have similar nickel content. Based on this evidence, it is very unlikely that the copper for sample C came from the same source

TABLE 9. ANALYSES OF ANCIENT COPPER OBJECTS FROM PERU AND BOLIVIA

	Chepén, Perú, utensil[1] %	Chepén, Perú, knife[1] %	Pacasmayo, Perú, utensil[2] %	Chepén, Perú, knife[1] %	Chancay, Perú, pick[3] %	Chancay, Perú, knife[3] %	Chepén, Perú, knife[1] %	La Toma, Bolivia, ax[3] %	Copacabana, Bolivia, ax[3] %	Tiahuanco, Bolivia, utensil[3] %	Tiahuanaco, Bolivia, utensil[4] %
Cu	99.62	98.61	98.41	98.25	98.20	97.70	96.68	99.84	96.36	98.64	95.65
Sn	0.02	–	–	tr.	–	–	–	–	–	–	–
As	–	–	1.55	–	–	–	–	–	0.5	–	–
Fe	–	–	0.03	–	–	tr.	–	0.07	0.7	0.4	1.63
Ni	–	–	–	–	–	–	–	–	–	–	–
Pb	–	–	–	–	–	–	–	–	–	–	0.1
Ag	–	–	–	–	–	–	–	–	–	–	–
Au	–	–	–	–	–	–	–	–	–	–	–
Bi	–	–	–	–	–	–	–	–	–	–	–
S	0.27	–	–	–	–	–	–	–	–	0.9	2.55
Sb	–	–	–	–	0.07	–	–	–	–	–	tr.
Co	–	–	–	–	–	–	–	tr.	–	–	–
Zn	–	–	–	–	–	–	–	–	–	–	–

[1]Mead (1915).
[2]Baessler (1906).
[3]Nordenskiold (1940, written commun.)
[4]Bowman (1908).

TABLE 10. ANALYSES OF MODERN COPPER OBJECTS FROM PERU[1]

	Vicús, Piura, lance	San Pablo, Cajamarca jewelry	Lambayeque, needle	Tantamayo, knife	Chimbote, fragment	Chimbote, fragment	Chan Chan, rattle	Cotush, Chavin, ax	Jauja, knife	Lurin, needle	Ayacucho, mace
Century	IV–VII	IV–VII	IV–VII	VIII–XII	VIII–XII	VIII–XII	VIII–XII	X–XI	X–XI	XII–XV	XII–XV
	%	%	%	%	%	%	%	%	%	%	%
Cu	99.86	98.12	99.54	96.75	98.19	98.25	97.23	97.25	98.35	99.73	97.57
Sn	–	–	–	0.19	–	–	0.05	–	1.26	–	–
As	–	1.18	0.21	1.21	0.77	0.53	1.67	0.48	0.45	–	1.35
Fe	0.04	0.04	0.06	0.02	0.02	0.01	0.01	0.01	0.07	0.03	0.08
Ni	–	0.03	0.05	0.03	0.62	0.02	0.07	0.02	–	–	0.05
Pb	–	0.07	0.02	–	0.06	0.01	0.29	0.18	–	–	0.07
Ag	0.04	0.09	–	0.62	0.02	0.83	0.01	0.05	–	–	0.05
Au	0.01	0.04	–	0.03	–	0.01	–	1.21	–	0.01	–
Bi	–	0.06	–	0.18	0.13	0.17	0.14	0.09	–	–	0.03
S	–	–	0.15	0.08	–	–	0.04	0.02	0.04	–	–
Sb	–	–	–	0.30	0.24	–	0.23	–	–	–	–
Co	–	–	–	–	–	–	–	–	–	–	0.01
Zn	–	–	–	–	–	–	–	–	–	–	–

[1]Caley (1970).

as the other two samples. The absence of sulfur indicates that the metal used for the three tools was sourced from completely oxidized ores. Sample C is notably free of impurities with the exception of arsenic. Similar metals could have been obtained by smelting arsenical copper.

COPPER METALLURGY IN NORTHERN CHILE

In reference to the great variety of impurities found in the analyses of copper and bronze objects found in the Atacama region of Chile, Latcham (1936, p. 115) considered that gold, silver, and zinc could have been intentionally added to copper. However, this was not the case for trace antimony, arsenic, sulfur, cobalt, iron, nickel, lead, and silicon which undoubtedly came directly from the copper and tin ores. In short, he says that "…the major amount of the copper silicates and copper carbonates from Chile were derived from oxidation of polysulfide ores that contained trace sulfides that are not oxidized and greatly impeded the ordinary methods of leaching. These minerals were the preferred minerals for ancient smelting, and upon smelting, trace sulfur remained. Other minerals in the north of Chile are copper, silver, and lead sulfides. Upon oxidation, the colorful minerals (carbonates, silicates) remain and through weathering, small amounts of these metals appear during smelting as the impurities iron and arsenic, which are also abundant in many minerals. Therefore, to make a complete analysis of the Chilean bronzes, it is possible that some of these have impurities which make them appear to have come from regions where similar geochemical analogues are found, however, were smelted in Chile." Latcham's arguments apply to all the ancient metalworking centers of ancient Perú.

The smelters used in the Atacama region were built in the ground, using crucibles and stone molds to receive the smelted metal. The archaeological evidence for the use of smelters for copper is found near Cobre, in the Diaguita-Atacama region, which is where Bowman (written commun., 1966) researched a pre-Colonial mining-metallurgical center and found a mine with chrysocolla ores, a stone mill, *huayras*, and broken crucibles with metal. The chrysocolla ore, the smelter scoria and fragments of metal from one of the crucibles were analyzed. The results demonstrate efficiency of the metallurgical process because a very pure copper, comparable to native copper, was obtained (Jiménez, 1924, p. 15) (Table 12).

TABLE 11. ANALYSES OF COPPER ARTIFACTS FROM PERU, TOOLS FROM THE ANCIENT FORTRESS AT TUMBES[1]

	Sample A	Sample B	Sample C
	%	%	%
Cu	98.11	98.01	96.38
Sn	–	0.65	–
As	0.47	0.20	0.85
Fe	0.01	0.09	0.02
Ni	0.07	0.07	–
Pb	0.61	0.23	0.02
Ag	0.05	0.10	–
Au	–	–	–
Bi	–	–	–
S	–	–	–
Sb	–	–	–
Co	–	–	–
Zn	–	–	–

[1]Caley (1970).

TABLE 12. ANALYSES FROM THE COBRES REGION, ATACAMA, CHILE[1]

	Chrysocolla (%)	Smelter scoria (%)		Metal (%)
Cu-ox	16.75	8.15	Cu	98.74
Fe-ox	51.20	49.00	Fe	0.92
Pb-ox	tr.	tr.	Pb	0.31
SiO_2	71.05	40.82		
Al_2O_3	0.13	0.33		
CaO	0.37	1.50		
MgO	0.07	0.13		
Volatiles	14.30	–		

[1]Bowman (1966, written commun.).

COPPER METALLURGY IN BOLIVIA

Information on the metallurgy of copper in the Tiahuanaco region of Bolivia was published by Ponce Sanginés (1970, p. 42, 55, and fig. 35):

> The Wankarani culture smelted copper both locally and in their villages. It is important to remember that at excavation pit 1 at the Wankarani hillocks, at 1.89 m depth, copper smelter scoria was found in place. Adding to this, similar smelter scoria was excavated from Pukara de Belén and at La Joya. These have been analyzed using spectrographic emission methods which helped to understand the source of some of the impurities. It is important to note this early use of copper for smelting and the transformation of mineral to metal in the Altiplano. This is evidence of Tiwanaku technology in Epoch I and that copper was smelted and put into molds.

At Chiripa, copper smelter scoria was found at the same stratigraphic level as at Wankarani and Tiwanaku. This is an eloquent testimony to the early and widespread use of this metal in the Altiplano. In figure 35, Ponce Sanginés (1970, p. 60) shows smelter scoria from: (1) Pukara de Belén, (2) La Joya, (3) Wankarani and in Tiwanaku, epoch I, Kalasasaya. At Chiripa, ceramic tubes were found that were used to supply forced air to the *huayras*.

CHAPTER 8

Alloys

Metals, whether native or smelted, have high melting temperatures which can be lowered significantly by the presence of impurities or other metals added as alloys. This was apparently known by the ancient Peruvian metallurgists who understood that alloys had certain advantages over pure metals such as higher tenacity and uniformity during smelting. They had bronze that contained copper, tin, and silver that were much harder than common bronze. Cases such as these and the extreme hardness obtained by hammering have given rise to the saying "The art of ancient Peruvian metallurgy is now lost."

The metals can be put into two groups (Table 13); in the first group, platinum and iron have melting points much higher than the temperatures obtained in the *huayras* using air forced in through *tuyeres*. Metallic iron is not produced for this and other reasons. For working platinum, sintering was used. The effect of cold-hammering on the hardness of the metals and their alloys is shown on Table 14 (see also Tables 15 and 16).

TABLE 13. MELTING POINTS OF METALS AND ALLOYS

Metal or alloy	T (°C)
Pt	1764
Fe	1530
Si	1414
huayra scoria	1300–1400
Cu	1084
Au	1063
Ag	960
bronze	950
Au-Cu (-Ag) (82% Au)	880
Ag-Cu (72% Ag, 28% Cu)	779
Zn	419
Pb	327.3
Sn	231
S	113
Hg	–38.9

GOLD-SILVER

The hardness of gold is normally 2.5 and it is at its hardest in the following proportions: 65% gold–35% silver or 75% gold–25% copper.

The purity of ancient goldwork varies in wide ranges as shown in documents from the Archivo de India about gold sent from Perú in 1534 (Mujica Gallo, 1959, p. 287). The 47 pieces shipped had a total weight of approximately 670 kg of gold, without counting the silver artifacts, and ranged from 9 to 21 carats:

11 pieces of 21 carats	1 piece of 13 carats
5 pieces of 20 carats	6 pieces of 12 carats
6 pieces of 19 carats	6 pieces of 11 carats
2 pieces of 18 carats	1 piece of 10 carats
2 pieces of 15 carats	1 piece of 9 carats
6 pieces of 14 carats	

The same variation in gold content is shown in the diverse gold adornments coming from the Chavin, Chongoyape, and Paracas regions (Lothrop, 1953, p. 85). Also see Table 17.

There is the general opinion that the ancient metallurgists intentionally produced alloys of gold and silver using pure metals, and explained that the range of composition that was observed was because of their inability to make the alloy a qualitative process. The certainty is that native gold is never pure. Examination of the analytical data of native gold (Tables 2, 3, and 5) and of gold artifacts (Tables 17 and 18) permit the deduction that the ancient metalworkers worked directly with naturally occurring alloys of gold and silver.

In ancient Perú, there exists no evidence that gold was refined.[23] It is very unlikely that they were able to achieve purity of 100% gold and even modern technology can only achieve a purity of 998–999 fineness using electrolytic processes.

In the case of the 100% gold crown from Chongoyape (Table 17), one can suspect that there were analytical problems. When the gold content is high, elimination of silver is difficult and the analytical percentage of gold can appear higher than it really is. It is also possible that the gold crown from Chongoyape was produced using gold from the Sandia region where gold purity may be as high as 98.5%, however, this is a rare case according to information from the Casa de Moneda in Lima.

Under special conditions, for example, when the gold contains silver, there exists the possibility of finding gold of exceptional purity in alluvial deposits, in fact, higher than the purity of the gold found in the source veins. It may be possible that, during transport, the river water may remove some of the silver contained in the alloy. This may explain why gold nuggets toward the exterior of alluvial gold outcrops have a higher gold purity than those in the interior of the units. Similarly, gold flakes may have a higher proportion of gold and a finer grain-size than the larger nuggets because of the groundwater flowing through the alluvial unit. The variation in other alloys can be attributed to changing mineralogical processes that produced the veins. Even with these considerations, it is clear that the ancient Peruvian metallurgist had a wide range of

TABLE 14. EFFECT OF COLD-HAMMERING ON THE HARDNESS OF ANCIENT ARTIFACTS FROM SOUTH AMERICA[1]

Metal/alloy	Brinell hardness smelted	Brinell hardness cold-hammered
Cu	30	100–135
Au	50	–
Bronze (5% Sn)	55	200
Bronze (10% Sn)	90	275
Ag-Cu (92% Ag, 8% Cu)	60	183
Au-Cu (80% Au, 20% Cu)	110	200
Au-Cu-Ag (52% Au, 26% Cu, 22% Ag)	150	200
Steel (average)	104	–

[1]Root (1949a).

gold purities at his disposal and did not have to rely on difficult refining processes.

Gold Chimú lip ornaments were found widely in northwest Perú (Petersen, 1955) and examples are known from burials in Tumbes, Los Organos, Sullana, Piura, and Lambayeque. This adornment was in use up until the early days of the Conquest. In May 1532, in the Tangarala Valley (Chira), Pedro Pizarro (1571, 1968 edition, p. 464) noted the use of gold and spoke of the clips and the clothing that the women wore that used gold and silver hooks that allowed them to place them where they wished.

TABLE 15. MOHS HARDNESS SCALE

Mineral	Everyday item	Mohs hardness scale
Talc		1
Gypsum		2
	Fingernail	2.5
Calcite	Mica	3
	Copper coin	3.2
Fluorite		4
Apatite	Glass	5
	Knife blade, nail	5.5
Feldspar		6
	Steel file	6.5
Quartz	Sandpaper	7
Topaz		8
Corundum		9
Diamond		10

TABLE 16. HARDNESS OF METALS ON THE MOHS HARDNESS SCALE

	Mohs hardness scale
Pb	1.0–2.0
Sn	1.8
Zn	2.5
Au	2.5
Ag	2.5–3.0
Cu	3
Fe	4.5
Fe+Ni	5.0–6.0
Pt	4.0–5.0
Pt+PGMs	6.0–7.0
Pd	4.5–5.0
Rh	6
Ru	6.5
Ir	6.5–7.0
Os	7

PGMs—platinum group metals.

One of the gold ornaments from the ancient burial site near the ancient city of Los Organos, Dept. Piura, was analyzed in the Laboratorio Espectrográfico, Corporación Cerro de Pasco, La Oroya (Inf. no. 452–21, XII, 1970, E. Manrique) and also in the Laboratorio de Analísis Químico Inorgánico, Universidad Nacional de Ingeniería (Inf. no. 25 875. 31.12.70, M. Macedo M.) and the results are given in Table 18. It is from the Chimú period, probably from the XII-XIII century (CP). It is a Au-Ag alloy with significant amounts of Cr, Ni, Pd, Pt, and Sn. The presence of platinum and palladium indicates a gold source in the central part of the country.

The alloy is 15.7 carats and is within the limits of native gold found in gold-bearing veins in the Zaruma region (15–19 carats); however, it is less than the carats from alluvial gold sources in the Rio Tumbes which average 17.5 carats.

These lip ornaments are of a very characteristic style and hundreds are in archaeological museums and private collections throughout the country. Given the limited regional distribution, a future study might include correlation of archaeological artifacts with the origin of the native gold used for its fabrication.

GOLD-COPPER

Gold-copper alloys have been found in coastal areas of Perú and Ecuador and were important in Colombia, where the products were traded northward to Central America and the southern part of North America. In Perú, *tumbaga* alloys have been known from about A.D. 500 to A.D. 1000 (Larco Hoyle, 1963); in Colombia since around A.D. 700; and in the Caribbean since about A.D. 1000. In general, *tumbaga* objects contain variable amounts of silver in the gold. In *tumbaga* from Colombia, the silver content may be 15%–20%.

Names:

Tumbaga or *tumbago*, named by the Spanish and likely from Sanscrit *tamraka*, or alloy; also a metal band of copper and zinc; a gold-plated metal; and now a name that is generally used in the Americas for an alloy of gold, silver, and copper.

TABLE 17. ANALYSES OF GOLD AND SILVER ARTIFACTS FROM PERU[1]

Artifact	Style	Gold (%)	Silver (%)	Copper (%)
Crown	Chongoyape	100.0	–	–
Pin	Chongoyape	26.0	74.0	–
Head ornament	Paracas	97.0	2.0	1.0
Head ornament	Paracas	97.0	–	3.0
Head ornament	Paracas	98.0	18.0	4.0
Adornment	Paracas	77.0	19.0	4.0 (tr. Pt)
Earspool	Chavín	81.2	14.3	–
Neck ornament	Chavín	72.5	23.7	3.8
Nose ornament	Chavín	71.6	24.2	4.2
Nose ornament	Chavín	71.0	22.0	4.2
Nose ornament	Chavín	52.6	40.0	7.4

[1]Lothrop (1953).

Guanine, in Haiti, low-grade ore.
Karakoli, used by the Arawak.
Antacori, in Quechua.
Champi, also Quechua, a mixture of gold with copper (Middendorf, 1890); alloy of copper, bronze, and gold (Perroud and Chouvenc, 1970).[24] In coastal Perú, the gold-copper alloy was common, however, according to the Castellano-Yunga dictionary (Zevallos Quiñones, 1947), the word used by the Moche and the Yungas has now been lost. In publications found in the libraries of several archaeological museums in Perú, the Quechua word *champi* has been improperly used for gold-copper alloys associated with the Vicús, Moche, and Nazca and produced along the central coast and in the central part of Perú centuries before Inca domination.

TABLE 18. ANALYSIS OF A GOLD LIP ORNAMENT FROM LOS ORGANOS, DEPT. PIURA, PERU (CHIMU, PROBABLY XII–XII CENTURY)

	Spectrographic analysis	Chemical analysis
Ag	M	34.5%
Al	V	
As	V	
Au	M	65.5%
B	V	
Bi	V	
Ca	V	
Cr	V	
Cu	m	
Fe	S	
Hg	V	
Mg	V	
Mn	V	
Na	V	
Ni	V	
Pb	V	
Pd	V	
Pt	V	
Si	V	
Sn	V	
Zn	V	

Note: Analyzed for: 48 elements. Detected: 21 elements. Key: M = >10%; m = 1.0–10%; S = 0.1–1.0%; V = <0.01%.

The gold-copper alloy, with or without silver, had a great advantage over either metal individually. The melting temperature was approximately 200 °C lower than the melting temperature of either of the metals as shown in Table 13. And, the presence of silver caused the melting temperature to be even lower. The hardness of the alloy and its eutectic mixture were greater than the hardness of bronze (Cu, Sn) (Table 14).[25]

According to Jijón y Caamaño (1922) and Lanning (1967), there are several variations of the basic gold-copper alloy:

Au-Cu	Titicaca; Moche, Early Intermediate
Au-Cu-Ag	Colombia, Ancón, Moche
Au-Cu-Ag-Zn	Colombia
Au-Cu-Ag-Pb	Bogotá
Au-Cu-Ag-Si-Bi	Quara
Au-Cu-Fe	Chimbote

Depletion Gilding

One of the qualities that was most appreciated about *tumbaga* was the ease with which a golden surface could be produced even with low gold content. This process, called "mise en couleur" or depletion gilding was described in the first accounts of metalworking in ancient Perú. Gonzalo Fernández de Oviedo (1525, 1950 edition, p. 253) wrote:

> They know very well how to gild copper pieces that have a low gold content; they do this and it gives an excellent color that looks as if the whole piece is of twenty-two carat, or more, gold. This color is done with certain plants that none of the expert Spanish, Italian, or any other metalsmiths have; one could become very rich with this secret method of gilding." López de Gómara (1552, 1954 edition, p. 124) wrote: "In Santa María, there is much gold and copper that is gilded using a special plant and treated manure; the piece is coated with this mixture which is then fire-dried: it takes on some color, more of the plant is added, the color is more beautiful and this is the metal that intrigued, and deceived, the Spanish.

Descriptions of the gilding process include those of Root (1959, p. 77): "In 1938, Bergsoe experimented with several gold-copper alloys to see if he would be able to gild an object in the manner described by López de Gómara. The alloy was heated to approximately 800°C until it blackened because of the oxidation of the copper at the surface. The piece was then submerged in an acid bath that dissolved the oxide leaving gold at the surface. Repeating this process removes more copper oxide and brings more gold to the surface. Results are impressive with an alloy of only 50% copper and with only one heating and bathing step. With an alloy of 75% copper, three to four heatings are necessary, with 90% copper the gold will come to the surface as a thin layer but is easily removed. This method of gilding *tumbaga* is most practical with 85% copper or less." See the discussion of this process by Easby (1965, p. 93).

In studies of different methods of gilding during Chimú time, H. Lechtman (Massachusetts Institute of Technology, personal commun., June 1970) indicated that many Au-Ag-Cu artifacts had been found from which both copper and silver had been removed thereby leaving a surface of gold; a similar effect had been produced by application of a mixture of iron sulfate, salt, and potassium nitrate; which when mixed become acid, and without application of heat, removed the silver and copper leaving gold in place on the surface. Fortunately, samples of melanterite, an iron sulfate mineral which occur in many mines, were obtained and analyzed. The data, presented at the XXXIX Congreso Internacional de Americanistas (2–9 August 1970 in Lima) by Lechtman (1970), showed that the Chimú metalworkers were expert at gilding metal objects.

For the study, several Chimú objects that appeared to be gilded were chosen. Chemical and metallurgical analysis and examination of fragments from the artifacts showed that the metal was a ternary alloy of copper, silver, and gold with gold content of 10%–40%. This is somewhat different from *tumbaga* which is known to be a gold-copper-silver alloy. After fabrication of the smelted alloy, copper was easily removed by oxidation and left a layer enriched in gold and silver. This layer is silver and gives the impression that the artifact was made using silver laminations or gilding. The gold surface was produced by depletion in which all the silver was removed thereby leaving an almost pure gold surface.

Among the objects on display in the Museo Oro del Perú, according to Mujica Gallo (1968), are more than 30 artifacts such as necklaces with beads and discs that are made of a gold-copper alloy and are classified as *champi*. These are from the Nazca and Chimú cultures.

The gold-copper alloy, used for Peruvian copper artifacts, can also produce a thin superficial coating upon being heated during the gilding process. In this case, there is a diffusion of the gold and copper. This process may remove some of the copper at the surface and the surface may then be treated several times in a mineral or plant bath to remove the remaining copper and leave a golden surface.[26]

The Museo Oro del Perú collection includes hundreds of vessels, crowns, masks, and other adornments from the Vicús and Chimú cultures and made from gold, silver, and copper much like the gilded copper from the "mise en couleur" process which all shows the great variation in the production and use of the type of alloy.

GOLD-PLATINUM

Platinum was also produced from alluvial deposits in ancient times and used in its native state without refining. Similar to gold and silver, platinum is also a ductile and malleable metal, qualities that permit its use in metalworking with only simple methods. The metallurgical technology consists of alloying gold and silver with platinum by sintering. Ancient objects of 55.60% platinum and 45.40% gold give the appearance of silver. In Ecuador, artifacts have been found that contain 70% gold, 18% platinum, and 12% silver.[27]

To alloy, or sinter, gold and platinum, the grains of platinum are mixed with gold flakes and the mixture is heated to elevated temperatures using charcoal. The gold melts and covers the surface of the platinum grains with a thin film of gold which now holds the platinum grains. The gold-platinum mass is now agglutinated, and is then reheated to help diffuse both metals. This bimetallic alloy is white, malleable, and by hammering, is easily converted into leaf or foil that can be applied in a variety of ways to decorate goldwork. Adhesion is also by agglutination. Undoubtedly, it is possible that the ancient goldsmith might have unknowingly used native gold with a high percentage of platinum for his goldwork (Table 5).

SILVER-COPPER

The silver-copper alloy varied considerably in composition and often the amount of copper was more than the amount of silver. For example, objects from Virú contained 12% silver and 88% copper. Objects made of this alloy have been found in coastal areas near Chincha, south of Lima.[28] According to Jijón y Caamaño (1922) and Lanning (1967), there are the following variations:

Ag-Cu	Pacasmayo; Ancón, Machu Picchu, Moche
Ag-Cu-S	Cusco, Machu Picchu
Ag-Cu-S-Fe	Machu Picchu
Ag-Cu-S-Pb	Machu Picchu
Ag-Cu-Pb	Machu Picchu

SILVER-TIN

A figure made of silver-tin and decorated with gold, silver, and copper, appears to have been produced as a single piece, and on its head, was a pointed cap. This piece, belonging to Lt. Col. Gamarra, was found in Cusco (Rivero and Tschudi, 1851, p. 324 and figure XLIV) and there is no other information on this rare ancient alloy.

COPPER-LEAD

This particular alloy is also known from ancient Mexico (Lothrop, 1964) and Jijón y Caamaño (1922) discuss this alloy, its impurities, and the sites where it has been found:

Cu-Pb	Cusco; Titicaca
Cu-Pb-Fe	Ecuador
Cu-Pb-S	Tiahuanaco; Cusco
Cu-Pb-Sb-Fe	Tiahuanaco; Yura and other sites
Cu-Pb-Sb-Bi	Valle de Quara
Cu-Pb-Sb-Fe-S	Paraná, Guazúa
Cu-Pb-Sb-Fe-Zn	Paraná, Guazúa
Cu-Pb-Fe-Zn	Tiahuanaco

Copper and antimony ores have been found in southeastern Perú as well as in the south of Bolivia; As, Bi, Pb, S, and Si are some of the impurities. Antimonial bronze has also been found at Machu Picchu. Bronzes with 2%–3% lead can easily be worked with sharp tools.

COPPER-SILICON

Modern bronze may contain 3.5%–4.5% silicon and this alloy is used because of its wear-resistance, for example, for overhead tram cables and the contact bars for trolleys. Copper silicate or hydrated copper silicate from chrysocolla may be used and will result in a final product with 1%–2% silicon which is sufficient to increase its hardness and wear-resistance.

Analyses of copper-silicon objects are rare,[29] however, Baessler (1906) lists several examples:

	Cu%	SiO_2%	Fe%	Pb%	Ag%
Forbes	88.05	11.2	0.36	–	0.17
Rivero	–	5–10	–	–	–
Boussinggault	95	4.5	tr	tr	tr
Vauquelin	96	4.0	–	–	–

Analyses by Rivero were done on a variety of copper objects such as chisels and axes and silicon was generally 5%–10%. It could not be determined if the silicon was intentionally added to increase hardness or if the silicon was a naturally occurring impurity in the ore. If silicon was found in all tools that were used and in idol production, then it is likely that the ancient metallurgists knew that addition of silicon would harden the copper (Rivero and Tschudi, 1851, p. 215).

Chrysocolla is ubiquitous in many copper occurrences along the Peruvian and Chilean coasts as well as in the Andes. Therefore, it is possible that several of the copper ores contained silicon and many of the copper analyses indicate that the copper was pure (Bowman, written commun., 1966). In order to obtain a copper-silicon bronze, excess silicon must be retained in the copper.

COPPER-TIN (BRONZE)

Bronze is a generic term that was originally applied to the copper-tin alloy and has also been applied to copper alloys, excluding brass, which contains zinc. The alloying of copper with tin gives certain advantages that include a lower melting temperature, ease of uniform smelts, and superior characteristics for general use. The criteria for this alloy vary greatly. Conventionally, the term "bronze" is used when the tin content is greater than 2%; however, some authors use a limit of 3%.

Bronze was first documented in China and was widely used from 1800 to 1500 B.C. In Egypt, bronze appears in the archaeological record after 2778 B.C.; in Europe between 1500 and 1200 B.C.; and at Cornwall around 1300 B.C. It is likely that the discovery and use of bronze took place independently at different times and places. In the Americas, the use of copper dates to the first millennium B.C. and the appearance of bronze took place in the later part of the first millennium. In Bolivia and northwestern Argentina, bronze was known to have been used before the Inca period, perhaps as early as A.D. 600 and its use dates to approximately A.D. 1000 in Perú.

In Quechua

Chayanta, copper mixed with tin, a white metal (Lira, 1945).
Antachay, mix copper with other metals.
Chajruska, *anta*, mixed copper metal (Middendorf, 1890).
K'ellwanta, *k'ellu*, yellow copper, used in mirrors (Middendorf, 1890).
Ch'umpi anta, bronze (Middendorf, 1890).
Llajsa, mixed metal, *llajsay*, to smelt, (Middendorf, 1890).
S^o anpi, *s^o oke*, bronze.
Llacsa, bronze, smelted metal (González Holguín, 1608).

In Aymara

Harcatha, mix, also *harkana*, *kit taña*, *kituña* (Torres Rubio, 1616).
Chaj'lltaña, mix.

Bronze Smelting

In order to produce their copper, the ancient metallurgists used ores of different composition and from different sources. Some of these mineral occurrences also contained tin as well as copper and this explains the presence of tin in varying amounts in objects from the IV–VII centuries. However, the amount of tin is not high enough to classify the object as bronze.[30]

There is considerable inconsistency between the purity of the tin that was used. Mead (1915) found the tin content of some of these objects to have been unusually high and could have come only from the natural tin content of the ores. C.H. Matthewson (oral commun., 1967) believed that there was a correlation between the difficulty of smelting certain objects and intentionally increasing the hardness. Wissler (1938) cites microscopic studies of certain objects that show that the property of increased hardness was a production technology and did not take place during the primary smelting of the ores.

Other techniques might have included:

- simultaneous reduction of copper and tin ores with charcoal;
- smelting of metallic copper and adding cassiterite and charcoal;

- smelting sulfide ores that had previously been roasted and then adding cassiterite and charcoal for simultaneous reduction which would have left sulfur in the metal; and
- smelting copper and metallic tin, in varying amounts, at elevated temperatures.

The analytical problems in the analyses of bronze can be explained if it is understood, that in ancient times, metal was sourced from a variety of occurrences and was smelted at temperatures above 525 °C.[31]

The tin content in Peruvian and Bolivian bronze varies from 2%–12% and Chilean bronze is commonly 3%–10% tin. Bronze with a tin content of up to 6% can be worked; small amounts of lead help the forging process for utensils and the bronze continues to be malleable. Among the numerous analyses published by Wissler (1938), there are a number of analyses which indicate that 3%–9% tin was common and show that bronze was produced in coastal Perú from the IV to the VIII centuries. Bowman (oral commun., 1968) is of the opinion that bronze from the Tititcaca region appeared during the Late Tiahuanaco period, around A.D. 1000. Latcham (1936) writes that bronze production took place along the Chilean coast between A.D. 1100–1300 during the Chincha-Chincha Atacameño period. Inca expansion took the use of bronze to Ecuador and possibly encouraged the export of tin from Bolivia northward. Along the coast and southern mountains of Perú, Bolivia, and northern Argentina, as in Chile, bronze was produced with relatively high tin content. Latcham (1936) thought that the metallurgists of the Diaguita and Atacameña regions did not use fixed amounts of tin, and instead, added tin according to their own metallurgical experience.

Mead (1915), Jijón y Caamaño (1922), Nordenskiold (written commun., 1940), and Lothrop (1953) indicated that ancient Peruvian bronze typically had 2%–12% tin. They suggested that there were two categories of bronze: one had low tin content which was used for bronze tools that could be hardened by cold hammering, and the other had a higher tin content and this bronze was used for adornments. At about the same time, in Ecuador, increasing the tin content helped to harden bronze that would be used for axes, knives, needles, and hooks. (See Tables 19 and 20.)

Of the bronze artifacts from Machu Picchu, Bingham (1948) found that the copper content of the bronzes was 86%–97%, which indicated that Inca bronze was exceptionally pure except for a small amount of sulfur. C.H. Matthewson (Yale University) studied more than 100 bronze artifacts from the Inca period, and according to Bingham, came to the conclusion that the tin content of these artifacts was not determined by their intended use, but rather more by the ancient metallurgical methods used for bronze production. Machu Picchu, during the Inca period, was evidently an important site for bronze, as well as copper and tin, production. A rolled belt of tin and small hearths for bronze-working were also found. These hearths also had holes for air and were three-legged (Bingham, 1948, p. 42–43).

It has been more than 170 years since Humboldt (1810, p. 89) traveled through the mountains in Cajamarca and obtained a bronze piece that was quite sensational: "...consider that the ancient Peruvians used copper that is mixed with a certain proportion of tin and thereby, becomes very hard. My suspicions were completely confirmed by the find of an ancient chisel near Cusco at a silver mine that was worked during Inca time, in Vilcabamba. This precious tool that I saw, thanks to Narciso Gilbar, is 12 cm long and 2 cm wide, and is composed of 94% copper and 6% tin according to an analysis by Vauquelin. This copper used for cutting by the Peruvians is very much like that which is used for the guillotine."

A Star-Shaped Bronze Clubhead

Dr. H. Trimborn, of the University of Bonn, Germany, who explored the Chala region, provided a star-shaped bronze clubhead that was analyzed by the Laboratorio Espectrográfico, Corpo-

TABLE 19. ANALYSES OF ANCIENT BRONZE FROM BOLIVIA AND CHILE

	Tiahuanaco, Bolivia, pin[1] %	Tiahuanaco, Bolivia, idol[1] %	Tiahuanaco, Bolivia, knife[1] %	Tiahuanaco, Bolivia, pin[1] %	Taltal, Bolivia, plate[2] %	Atacama, Chile, ax[3] %	Chin-Chin, Chile, chisel[3] %	Chin-Chin, Chile, chisel[3] %	S.P. de Atacama, disc[3] %	Calama, Chile, earring[3] %
Cu	87.26	88.76	89.76	93.22	84.25	88.20	88.44	86.22	87.54	94.32
Sn	12.36	9.01	7.98	6.18	10.74	8.14	5.66	4.30	3.26	2.48
As	–	–	–	–	–	–	–	–	–	–
Fe	–	–	–	–	–	–	–	–	–	–
Ni	–	–	–	–	–	–	–	–	–	–
Pb	–	–	–	–	–	–	–	–	–	–
Ag	–	tr.	–	–	–	–	–	–	–	–
Au	–	tr.	–	–	–	–	–	–	–	–
Bi	–	–	–	–	–	–	–	–	–	–
S	–	–	–	–	–	–	–	–	–	–
Sb	–	–	–	–	–	–	–	–	–	–
Co	–	–	–	–	–	–	–	–	–	–
Zn	–	–	–	–	–	–	–	–	–	–

[1]Posnansky (1945).
[2]Jijón and Caamaño (1922).
[3]Latchman (1936).

TABLE 20. ANALYSES OF ANCIENT BRONZE FROM PERU

	Machu Picchu, knife[1] %	Machu Picchu, chisel[1] %	Machu Picchu, ax[1] %	Machu Picchu, knife[1] %	Machu Picchu, ax[1] %	Western Perú, ax[2] %	Western Perú, ax[2] %	Vilcabamba, chisel[3] %	Cusco, ax[4] %	Huanta, ax[5] %
Cu	90.09	93.90	93.70	94.26	95.63	93.94	96.44	94.00	95.45	92.06
Sn	8.99	5.53	5.01	4.82	3.99	5.58	3.36	6.00	3.64	5.07
As	–	–	–	–	–	–	–	–	–	–
Fe	–	0.06	0.87	0.32	–	–	tr.	–	0.09	–
Ni	–	–	–	–	–	–	–	–	–	–
Pb	–	–	–	–	–	tr.	–	–	–	0.12
Ag	0.68	–	–	–	0.37	0.65	–	–	0.04	0.03
Au	–	–	–	–	–	–	–	–	–	0.06
Bi	–	–	–	–	–	–	–	–	–	–
S	0.13	0.15	0.44	0.23	0.40	0.08	0.23	–	0.48	–
Sb	–	–	–	–	–	–	–	–	–	–
Co	–	–	–	–	–	–	–	–	–	–
Zn	–	–	–	–	–	–	–	–	–	–
total	99.89	99.64	100.02	99.63	100.39	100.25	100.03	100.00	99.70	99.32

[1]Matthewson (1915 written commun.).
[2]Foote and Buell (1912, written commun.).
[3]Humboldt (1910).
[4]Caley (1970).
[5]Bonavia (1970).

ración Cerro de Pasco, La Oroya (Inf. 452.Oroya, XII.819.1970, E. Manrique) and the Laboratorio Análisis Química Inorgánica, Universidad Nacional de Ingeniería de Lima (Inf. no. 25873. 31.XII.1970, M. Macedo). The results are given in Table 22 and show that the composition of this bronze artifact is different than the compositions given for bronze pieces in Tables 19 and 20 with respect to Bi, Ni, Mn, Mo, Pb, and Ti.

COPPER-ARSENIC

The use of arsenic to harden copper dates to ancient times in the Old World and only 0.65% arsenic is needed to give copper resistance to deformation. Arsenical copper objects were found in the Middle East that date to the Early Sumero period (before 2358 B.C.). In Egypt, copper-age objects (approximately 3000 B.C.) have arsenic as an impurity, possibly as a residual from the arsenical copper ores of the Sinai. During the XII dynasty (1965–1792) copper began to be hardened by the addition of arsenopyrite and arsenic-containing ores to the smelt. Copper was smelted with 1.2%–4.7% arsenic that was mixed equally with low-grade copper ores from the island of Chipre. In central Europe, copper with 1%–8% arsenic was used for utensils and weapons.

The alloy, brass, contains copper and zinc, and with 2% arsenic can be given a bright polish. Alloys with more than 3% arsenic become burnished and cannot be worked. Special-use alloys may have as much as 8% arsenic.

The most ancient copper-arsenic objects in Perú were found in Lambayeque and Cajamarca and were from Early Moche time. Farm tools and ornaments were produced and were easily made in molds.

Caley (1970) proposed a nomenclature based on the arsenic content, for example, copper artifacts with up to 2% arsenic were called arsenical copper, however, when the arsenic content was greater than 2%, and there was no tin, the term arsenical bronze was used.

Pre-Columbian arsenical copper and arsenical bronze have been found in northwestern Argentina, Bolivia, and Chile. Caley (1970) has compiled data and included arsenical bronze objects from Perú in order to better document the regional use of arsenical bronze. These data are given in Caley (1970, tables VII and VIII) and in Table 21.

Jijón y Caamaño (1922) discuss other alloys that are limited to the central Peruvian coast:

Cu-As-Fe-Pb-S	Chan Chan
Cu-As-Fe	Pacasmayo

Occurrences of arsenical copper ores are found along the Andean cordillera in Perú, Bolivia, and northwest Argentina. Native arsenic is known only at Caracoles and Copiapó (Ramdohr, 1969, p. 370) and native arsenic was rarely found in Perú. The list of copper-arsenic minerals available to the ancient miners and metallurgists includes arsenopyrite, chenevixite, enargite, and tennantite.

In the semi-arid climate, chenevixite, a supergene mineral, is found in weathered zones with veins that may also have arsenopyrite, enargite, and tennantite. In view of the fact that ancient underground copper mining was not especially advanced, copper oxide minerals closer to the surface generally offered ease of smelting. In the case of chenevixite, the arsenic content was 7%–18%, and it was likely collected along with the other copper minerals found in the supergene assemblage.

Smelting the arsenic-containing minerals from the supergene zone may also explain the trace amount of arsenic found in many copper artifacts (Tables 7 and 9) and it seems unlikely to have any other metallurgical explanation. Most of the arsenic, as

TABLE 21. ANALYSES OF ANCIENT ARSENICAL BRONZE FROM PERU AND ARGENTINA

	Lima, Perú, utensil[1] %	Chancay, Perú, pick[2] %	Trujillo, Perú, utensil[1] %	Batan Grande, Perú, foil[3] %	Batan Grande, Perú, rattle[3] %	Batan Grande, Perú, lance[3] %	Chan Chan, Perú, lance[4] %	Argentina, belt[5] %	Argentina, ax[5] %
Cu	95.22	95.62	95.95	96.36	92.75	94.35	97.43	92.33	91.56
Sn	–	–	–	0.01	–	–	–	2.05	0.91
As	4.43	4.27	4.03	2.91	3.07	2.67	2.14	3.40	6.88
Fe	0.21	–	0.05	0.06	0.04	0.02	tr.	tr.	–
Ni	–	–	–	0.16	2.68	0.02	–	–	–
Pb	–	–	–	0.07	0.06	–	–	–	–
Ag	–	–	–	–	0.07	0.03	–	–	–
Au	–	–	–	–	0.02	–	–	–	–
Bi	–	–	–	0.18	0.25	0.15	–	–	–
S	–	–	–	–	–	–	tr.	–	0.25
Sb	–	0.08	–	0.05	0.26	–	–	0.42	0.32
Co	–	–	–	0.01	0.01	–	–	–	–
Zn	–	–	–	–	–	–	–	1.22	–

[1]Baessler (1906).
[2]Nordenskiold (1940, written commun.).
[3]Caley (1970).
[4]Loeb Morey (1910, written commun.).
[5]Fester, (1962).

TABLE 22. ANALYSIS OF A STAR-SHAPED BRONZE CLUBHEAD, CHALA, PERU

	Spectrographic analysis	Chemical analysis
Ag	W	
Al	V	
As	V	
B	V	
Bi	V	
Ca	V	
Cr	V	
Cu	M	95.00%
Fe	S	
Mg	V	
Mn	V	
Mo	V	
Na	V	
Ni	V	
Pb	V	
Si	V	
Sn	m	5.00%
Ti	V	
Zn	V	

Note: Analyzed for: 48 elements. Detected: 18 elements.
Key: M = >10%; m = 1.0–10%; S = 0.1–1.0%; W = 0.01–0.1%; V = < 0.01%.

an oxide, would volatilize at the elevated melting temperatures of most copper ores because of its low temperature of volatilization. The copper obtained would be almost pure and have a low arsenic content which would be further reduced by reheating during artifact production. Therefore, the existence of arsenical bronze with high As content is very likely due to the addition of arsenic sourced from specially selected minerals such as arsenopyrite with 46% arsenic or tennantite with 20% arsenic. True arsenical bronzes would have had a variable arsenic content, as shown in Table 21, and can only be explained by the lack of quality control that the ancient metallurgist was able to exercise during the metallurgical process.

There are several mines or occurrences of arsenical copper that were likely used by the ancient miners and these include Cajamarca, Cuzco, Huarón, Huaylas, Ilo, Maravillas, Morococha, Lake Titicaca region, Quirivilca, Sayapullo, Cajatambo, Salpo, Vilcabamba, and others in Bolivia and Argentina. There is also sufficient evidence that Colquijirca, Hualgayoc, and Cerro de Pasco were mined in ancient time. Copper-arsenic minerals in the upper zones of these occurrences were likely used to produce arsenical bronze during pre-Columbian time. In the early days of the Conquest, the Spaniards seemed interested mainly in silver; however, extraction was labor-intensive and this was not to change for almost three and a half centuries. There was no longer a demand for copper because the arrival of the Spanish had brutally introduced the ancient Peruvians to the Iron Age.

OTHER COPPER ALLOYS

The following lesser-known copper alloys are listed in Jijón y Caamaño (1922):

Cu-Fe	Chimbote, Trujillo, Chepén, Pachacamac, Cusco, Titicaca, Tiahuanaco
Cu-Fe-S	Machu Picchu, Titicaca, Tiahuanaco
Cu-Fe-Zn	Lima
Cu-Fe-Ni-Co	Salta
Cu-Zn	Machu Picchu
Cu-Sb	Chepén

CHAPTER 9

Metalworking and Fabrication

The techniques used for ancient handicrafts and metalwork have been described by a number of authors including Cieza de Leon, Benzoni, Garcilaso de la Vega, Root, Mujica Gallo, and others. Benzoni, who arrived in Perú in 1547 made significant observations of ancient Andean metal work which were also produced as illustrations. Benzoni (1565 and 1572, translated from Italian by Radicati di Primeglio, 1967, p. 62–63) observed that … "When gold and silver are smelted, the metal is put into a crucible that was made from a wet-clay and charcoal mixture; then, when the crucible has dried, the metal to be alloyed is put inside the crucible, which is then set in the oven and five or six tuyeres, are used until the alloy is completed and then cooled. Then, the craftsmen, who are seated on the earthen floor, using black rocks especially prepared for metal work, help one another to work and produce figurines, vessels, jewelry, and all types of animals that they have seen."

Many of these metal-working tools have been found and include:

- Anvils, polished and rounded, to 30 cm in diameter, made of dark green porphyry, at Huaca de la Hacienda Caudevilla, Carabayllo (Saenz, 1892).
- Hammers, different shapes, rounded to square, of basalt, gray to dark red andesite, rhyolite; Lothrop (1950, p. 160) discusses hammers and other tools used for metal-working.
- Mortars, of quartz porphyry and lapis lazuli, Ancón.
- *Tuyeres*, copper tubes of varying sizes; fragments have been found in ancient Chimú burials when the Hotel de Turistas was built at Tumbes.

At a burial at Huarmey, Lothrop (1954, p. 31; 1955, p. 146) found a number of stone and metal tools that had been used during the lifework of the craftsman who lived during Chimú time.

COLD-HAMMERED ARTIFACTS

For cold-hammering, the most ancient metalworking technique, a stone hammer and an anvil of hard igneous rock that served as the base, were used. Native gold is malleable and nuggets and gold flakes were used for many large artifacts. The internal structure of the gold was changed during hammering and the pieces became harder. Therefore, it was necessary to reheat and temper the piece one or two times as needed. Reheating required great skill because if the piece were overheated, it would melt. Cold-hammering was known since the Chavín time. Silver, copper, and bronze pieces were similarly treated. Similar techniques were used for setting gemstones as well as etching and embossing. There are many examples of gold wire that were widely used as well as large sheets of gold that were used as decoration on the walls of sanctuaries and public buildings. The most spectacular hammered objects were undoubtedly the large embossed sheets that were used to decorate the vestibules and walls of temples. Several examples from Chimú time, on display in the Museo Oro del Perú, are from the Lambayque region as well as from the Coricancha at Cusco where gold sheets were used to decorate the doors, walls, and gardens. These gold sheets were paper-thin and the hammering was done on wooden forms using stone hammers made from rhyolite, basalt, or other.

WELDING

To weld or solder decoration on metal objects, gold was melted on small charcoal blocks by using a blowpipe until the gold absorbed some of the carbon; the metal was heated to approximately 800 °C. Impure gold was also used and the impurities lowered the melting temperature.

AGGLUTINATION

The process of agglutination, or sintering, was used mainly to combine platinum with gold and silver, which would then be used to gild copper objects. In Colombia, Ecuador, and Perú, "white" objects of platinum, gold, and silver have been found. Although platinum is known in Perú, it is more likely that platinum was sourced from alluvial gold-platinum occurrences in Colombia. Even using a blowpipe, platinum could not be smelted or worked with the temperatures available to the ancient metallurgist. Platinum could be effectively alloyed with gold by the agglutination or sintering method and then by prolonged heating and hammering.

GILDING

There are several methods for gilding copper objects. This has been suggested as similar to amalgamation (Antze, 1930, 1965), however, there is no conclusive evidence in ancient Perú. The process basically consists of grinding two parts lead and one part gold to a powder and adding this to a mixture of resin which will be used to coat the objects. The piece is then heated to volatize the lead and the gold adheres to the copper as a gold-copper alloy. This procedure is repeated several times, as necessary, to obtain a layer of gold which can then be polished.

According to Larco Hoyle (1945b, p. 17, 24) "the copper object was covered with a thin coating of gold that appeared to have been applied at one time, and when the copper began to oxidize, the gold layer began to separate. We have found thin sheets of these gold foils which are as thin as fine silk." Also see the section on gold-copper alloys.

CASTING (LOST WAX)

In order to cast small metal objects, the metallurgists used small ovens, tuyeres, crucibles, and molds of clay mixed with gypsum. For their craft, the goldsmiths commonly used a method called "lost wax." The form was made using a mixture of finely crushed charcoal and clay which provided a solid, compact mass. Then, wax was added and then, more powdered charcoal. The piece was placed in the oven which was heated by tuyeres, was then bathed in alum, then placed back in the oven, and then was finally covered with a gold paste (Bargalló, 1955, p. 34).

Mujica Gallo (1959, p. 9) describes the lost wax method as molding the piece by using a semi-hard resin, and then covering it with a fine clay coating. Then the clay-covered form is heated, the wax melts, and flows out through a hole. Once it is cooled the ceramic mold is destroyed.

For making copper tools, the process was much simpler. A mold is made from wood or stone and covered with refractory sand and then the opening is filled with smelted metal. Hollow stone pieces have been found which were likely used as molds.

Research by Marshall (1964), Petersen (1969a), and Bonavia (1970) on pre-Columbian metalwork in Perú has further added to the knowledge of metallurgical processes and production and answered many questions that have existed in the study of archaeometallurgy.

Archaeological evidence and study of pre-Columbian technology indicates that a great number of resources were available to the ancient Peruvian metallurgist including stone and ceramic smelters, crucibles, and forms made of compacted clay. They made and used bronze, stone, and copper hammers as well as hafted axes of the same material or using wood. The treatment of gold, silver, and copper ores required the use of smelters that took advantage of natural air currents and did not require bellows. *Tuyeres* of cane or copper were also used to increase the temperatures in the smelters. The 20–22 carat gold that was naturally available did not require further refining and the fact that the gold contained silver, or electrum, provided a natural alloy. By using chemical baths of other metals, the silver content could be made to appear greater.

In some cases, pre-Columbian technology has not been adequately appreciated; however, this is because their techniques have been seen with a western mind which, in some cases, has led to misinterpretation.

CHAPTER 10

Mirrors

A large number of ancient mirrors have been found at archaeological sites in Perú. These were discussed and their importance noted in 1940, by J.C. Muelle. Mirror production required the use of anthracite, metals, minerals, rocks, and stones and it seems that these were used since the most ancient times in Perú.

In Quechua, *rirpo*, (Sto. Tomás, 1560); *wirpu*, *lirphu* (Ricardo, 1586); *rirpu*, *lirpu*, (Gonzáles Holguín, 1608); *lirpu*, or pyrite, a yellow metal in octahedral crystals, the surface of which reflects light. Also, *rirpu*, *lirpu*, a shiny surface to reflect light, a mirror (Middendorf, 1890; Lira, 1945). In the book, "Políglota Incaico de los Misioneros Franciscanos," *ccahuacona-cquespe* and *quespi* (Aymara) were used to indicate a mirror (Muelle, 1940, p. 6). Also, *ccahuacu-napakj-ckespe*, a glass with which to see oneself.

ANTHRACITE

The first ancient mirror found in northern Perú was from the Cupisnique culture (Larco Hoyle, 1945a, p. 10). Anthracite or *cisco* was used and polished until it was convex and could reduce an image (Larco Hoyle, 1963, Fig. 25). Another convex anthracite mirror was found at Oyotún (Muelle, 1940). In the Museo Oro del Perú are 24 anthracite mirrors, two of which have wooden handles. And also on display is a necklace with 15 pieces of polished anthracite that look like mirrors (Vitr. 1, no. 44 and 215). In the Museo Nacional de Antropología y Arqueología, there is an anthracite mirror that is 68 cm in diameter and 10 mm in thickness (Muelle, 1940). Evidence from studies at pre-Ceramic sites along the Peruvian coast indicates that polished anthracite mirrors have not been found before the Early Horizon (Engel, 1958).

GOLD

Columbus, upon arriving in the Americas, found a gold mirror. In looking for more information, Loredo (1958) lamented the fact that few of the gold pieces sent from Perú to Spain went to museums. He found a letter from Melchor Verdugo (dated 8 March 1543) which indicated that he had sent 22 emeralds, a gold ingot, a shawl with embroidered goldwork, 20 or so combs, and mirrors of gold to his sisters; all of which were from Trujillo, the region famous for gold and also known as Gran Chimú. Francisco Pizarro owned two mirrors with fine goldwork (Loredo, 1958, p. 32).

SILVER

Garcilaso de la Vega described polished silver mirrors that were used by the women of the royal court (1609/1941, Libro II, cap. 28, p. 205).

OBSIDIAN

There are two types of mirrors that have been found in ancient burials according to Juan and de Ulloa (1751, I, p. 463) and these were of obsidian, mistakenly called "Inca stone." The term "Inca stone" was used in ancient Chile for pyrite; however, in Ecuador, the term refers to a rock. Juan and de Ulloa (1751) described it as a stone that is not transparent and is gray and smooth. The mirror was generally circular and one surface was decorated as finely as any glass mirror and the other side was oval to spheroidal and not nearly as well-polished. There are various sizes with most being from 7 to 10 cm in diameter and one was found that was 46 cm in diameter. The surface is concave and gives a good reflection. The disadvantage of this type of rock is that it may have many veins and marks that distort the reflection and also may permit breakage.

There are adits from which this mineral may be taken in the valleys in the region. Two examples of this type of mirror are shown in Juan and de Ulloa (1751, Lam. XVI, figs. F and G). The description is somewhat vague and does not allow classification of the specific rock type that was used, and there is the chance that the rock might also have been a slate with veinlets of quartz and calcite.

Gallinazo stone is hard, fragile, conchoidal, and black, hence, use of the term *gallinazo*, which refers to a large, black buzzard that is common in the region. The mirrors are worked on both sides, circular, and have a hole so that a cord can be attached and then hung around the neck. There are both concave and convex examples. Usually this term refers to the obsidian that crops out near Quito and there are examples of this type of mirror in the Copenhagen Museum and also in Ecuador (Muelle, 1940). In the Museo Oro del Perú, Lima, there is a Chimú necklace (no. 4958), as well as a Vicús mirror (no. 4948), both of which are made of obsidian.

HEMATITE

Hematite can easily be polished and gives a brilliant black shine. Mirrors of hematite, thus far, are known only in Mexico.

BRONZE

During excavations at Machu Picchu, Bingham (1948) found several bronze mirrors. There was one concave bronze mirror that, upon polishing, concentrated the rays of the sun and ignited cotton cloth. Another bronze mirror was found at Cusco (Muelle, 1940). At Tiahuanaco, a bronze mirror was found that was 10.5 by 7.5 cm and now is completely corroded. When new and completely polished, it worked very well as a mirror. On the upper part and in the center was a hole so that it could be hung as a necklace and it is now at the Ethnographic Museum, Munich (Posnansky, 1957, p. 129).

Muelle (1940, p. 6) indicated that "In regard to the material used for mirrors, it is said in Los Comentarios Reales (L. II. Cap. XXVIII) that the mirrors used by women of royal blood were of highly polished silver and those used by others were simply polished metal, possibly pyrite, or brass." One of these is shown in Baessler (1906, Fig. 300) and is from the Museum Altperuanische Metallgeraete, Berlin. There is also a gilded bronze disc that is 10.1 cm in diameter that weighs 188.2 g and has a decorated surface of the same metal with a small loop so that it could be hung as a necklace.

In general, all the mirrors had an attachment so that it could easily be hung around the neck. As **Spondylus** necklaces were used as a commodity, Pilot Bartolomé Ruiz noted that mirrors decorated with silver, possibly for the same purpose, were seen in the indigenous canoes that he saw during his travels. These might have even been en route to Chile where the mirrors were called *lilpu.* Even until the end of Colonial time, pyrite was known as the "Inca stone." Therefore, a mirror made of pyrite, or *azófar* (from Arabic, also *acofre* or *latón*) is yellow but does not contain gold. However, according to Baessler (1906), the composition is 90.64% copper and 9.38% tin with traces of iron, and therefore, is a bronze and not brass, which would be a copper-zinc alloy.

PYRITE

Mirrors made of pyrite have a special beauty and come from many coastal regions of Perú:

- Huacho, a mirror of equal-sized pyrite crystals was found by Col. E. Garcia Moreno, and Max Uhle found a pyrite mirror at Cañar, Ecuador.
- Ica, at the Anthropological Museum of Berlin are three pyrite mirrors that originally came from Ica. The mirrors are disc-shaped with a polished surface and have wooden handles (Schmidt, 1929).
- Pachacamac, a pyrite mirror was found by Squier (1878).
- Paracas, a small, polished pyrite mirror with a wooden holder, now in the Museo Nacional de Antropología y Arqueología, Lima, no. 25205–157–163, (Muelle, 1940). Another was a polished pyrite mirror decorated with eight **Spondylus** and turquoise beads and perforated.
- San Lorenzo, Callao, a pyrite mirror was found at the extreme north part of the island.
- Central to south coast, a beautiful example of a pyrite mirror decorated with turquoise and shell, Tiahuanaco style, Robert Woods Bliss Collection, Dumbarton Oaks, Washington, D.C., (Lothrop et al., 1959, Plate CXXVI and CXXVII).[32] See Figure 13A, 13B, and front cover.

VOLCANIC ROCK

In pre-Ceramic tombs at Asia, south of Lima, mirrors of polished volcanic rock have also been found (Engel, 1958).

ENDNOTES

[1]Tools found along with **Megatheriidae** (an extinct ground sloth) remains, at Pikimachay, a cave in the Ayacucho Valley, have a ^{14}C age of 12,000 B.C. (MacNeish et al., 1970). Skeletal remains of the most ancient humans found in South America (jawbone of a woman, premolar of another individual, a finger) and other artifacts (hammer, a grinder, points, a scraper, ochre) were found in the Guitarrero cave near the Shupluy village, 6 km from the old Yungay village, and gave a ^{14}C age of 12560 ± 360 or 10610 B.C. (Lynch and Kennedy, 1970). In 1971, MacNeish et al. recalculated this age to be approximately 19,000 years.

The ancient lithic industry worked with fragments of quartzite, obsidian, and flint and these were made into tiles, points, and other useful tools. Indications of this industry have been found in the mountains of Argentina, Chile, Perú, Ecuador, and in the coastal areas of Tierra del Fuego, Chile, and Perú. Lanning and Hammel (1961) proposed the following classification:

Period I	10000–8000 B.C.	chance finds of objects
Period II	8000–6000 B.C.	chance finds of objects
Period III	6000–3000 B.C.	artifacts, batanes, foundations of dwellings
Period IV	3000–1200 B.C.	nomads, hunters, farmers
Period V	since 1200 B.C.	introduction of ceramics

[2]In Quechua, *coya* indicates a mine; *mama*, a vein or metal-bearing vein; *corpa*, sulfide minerals that contain lead, copper, or silver; *soroche* or *sorojchi*, specifically galena, however, may refer to other sulfides; *huayra,* a stone or ceramic smelter that used draft air; and *llimpi*, cinnabar or any red colored substance.

[3]The name of Alvaro Alonso Barba is generally written incorrectly and Alonso is used in place of his paternal surname. In Armando Alba's prologue, written for a new edition of "Arte de los Metales," he writes that P. Alvaro Alonso Barba was born in Lepe, Spain and was baptized on November 15, 1569 in the Iglesia de Santo Domingo. His father's name was Alvaro Alonso and his mother was Teresa Barba. Bargalló (1969, fig. 47) includes a copy of the document from the third book of Bautismos del Archivo de la Parroquia de Santo Domingo Guzmán, de la villa de Lepe. A. Alonso Barba died in Sevilla in 1661 at the age of 92.

[4]Acronyms: MGI—Museo Geológico, Departamento de Geología de la Universidad Nacional de Ingeniería; CR—A. Raimondi collection, Universidad Nacional de Ingeniería and Museo Javier Prado; CP—collection of the author.

[5]This ceremony was called *huatcuna* and an offering of the dust was made first to the *huacas* or *conopas* (idols) and then was blown to the wind (Tschudi, 1891). The word *huatcuna* may be related to *wat'ekk*, an instigator or impulsive person; *wat'kka*, a devil or demon; *wat'ekkay*, seduction for something illicit, or to fall into danger (Lira, 1945). The sacrifice had two purposes, one was to show reverence for the gods that lived in the sanctuaries, and for the domestic idols, to exorcise the bad spirits from the homes so that they would not cause harm to anyone.

[6]In 1945, we watched miners who were working the gold veins at Rinconada de Ananea using very primitive methods. The ore was mined and then crushed using a stone crushing mill and the women picked the minerals and concentrated the gold using a *batea*. The miners lived under the rocky cliffs at more than 5000 m which makes Nevado Ananea one of the highest inhabited places in the world. Figures 1–3 show the methods that were probably also used in pre-Columbian time. Raimondi (1879) precisely describes the adits, the mining, and the nearby town of Ananea.

[7]Padre Cobo (Cobo, 1956, p. 27, footnote 27) does not explain the word *aventadero*, which describes the method used to produce gold from alluvial deposits as discussed in "Historia geographica e hydrográphica…del reyno de Chile" which was submitted to King Carlos III in 1760 by the governor and Captain Manuel Amat y Junient. In one section about Collao, he indicated that the mountains had many gold veins and, at one place in particular, there is a special way of mining the gold which gives it the name *aventadero*. It is a sandy area near the foothills of the mountains and gold is found as nuggets and fine grains. The method of separating the gold from the sand is to throw it into the air or *aventarlo*, as is done with wheat, so that the air separates the sand, which is lighter, from the gold, which is heavier and falls to the ground to be collected by the miner or *aventador* or *aventadero*.

[8]This procedure is not isolated and is also done in the gold regions of southeastern Perú. During reconnaissance in 1933 in the Tambopata and Sandia-Sina valleys, we visited Sima (2931 m) and saw a gold site that had been intensively mined during Colonial time, with the exception of areas with dwellings and a dam that provided water for washing the gold. A map and cross-sections are shown in Petersen (1965, plate 32). While in the streets of the town, we had the opportunity to wash the gold concentrate, using a *batea*, from the *aventadero* and were able to recover some gold, locally called *chispitas* because of the flash of color from the metal.

[9]In 1969, Ing. J.A. Proano obtained a sample of *escoria* (smelter scoria or slag) from the Playa Hermosa archaeological site which is 1 km south of Ancón. Spectrographic and chemical analyses were done by the Cerro de Pasco Corp., La Oroya. Spectrographic analysis indicated that lead (>10%) was the major component and calcium, iron, potassium, and sodium were minor components (1%–10%). Other elements included silicon (0.1%–1%); silver, aluminum, and magnesium (0.01%–0.1%); and arsenic, boron, barium, bismuth, chrome, copper, manganese, molybdenum, nickel, tin, strontium, titanium, vanadium, and zinc (<0.01%). Chemical analysis indicated: copper (0.06%), lead (54.4%), zinc (0.40%), silver (19 oz/ton), and gold (0.005 oz/ton). The analyses suggest that the ore was a lead-silver ore that was probably brought from the cordillera. Finding this material at an archaeological site suggests the need for future studies. (Inf. no. 580-ES-69, Ing. Cueva, 12.4.1969 and C-4862 de 7.4.1969)

[10]The most important iron deposits in Perú include: Tambogrande (Piura); Zaña (Lambayeque); Yaurilla, Tinguiña, Marcona, Chala, Casca, Tarpuy, Cerro Mirador (Arequipa); Sama (Moquegua); Aija, Cerro China, Cerro Orcco, Calleycancha (Ancash); Iscai Cruz, Santa Lucía, Hierro Magnate, Caballo Uyo, and Pucará (Puno); Vinchos and Catahuariyoc (Pasco); Torrioc (Junín); Huacravilca (Huancayo); Andahuaylas (Apurímac); Canas-Livitaca, Chumbivilca, and Huine (Cusco); and Pebas and Nauta (Loreto).

[11]The Atacameños, in Chile, also do not produce iron because of the high temperatures required (Solari, 1967).

[12]In the ancient world, the use of iron dates to approximately 4000 B.C. in Egypt and the few objects that have been found contain trace nickel, an element common in iron meteorites. After about 2500 B.C., artifacts without nickel have been found indicating that the metal was obtained from ores. For the Sumerians, iron without nickel appears at about 3000–2700 B.C. and in Crete at about 2000 B.C. The Phoenicians traded in iron since 1825 B.C. In Europe, the use of iron dates to approximately 1000 B.C. (Hallstatt period, 800–500 B.C.)

In the Americas, the use of iron is also indicated by iron from meteorites. Alcina Franch (1965; 1970, p. 319–331) and Rivet and Arsandaux (1946) conclude that a worksite was found near Smith Bay, northern Alaska, where meteoritic iron was worked. The Eskimos from Ovifak, Greenland used iron from basalts. Native Americans in the western United States used iron from the Hopewell period up until the beginning of the Christian era.

Occurrences of meteoritic iron are very scarce and widely scattered with only a few spectacular exceptions. Meteorites that weigh more than 5 kg are rare. Of the 1059 meteorites that are known, only 8% are iron meteorites and some of these have been found in the Americas. The volume of other types of meteorites is far too small to have been used by pre-Columbian people for any sort of iron industry. Regardless, data on iron meteorites needs to be updated. The presence of nickel in artifacts is supposedly an indication that an iron meteorite was the source of the iron, however, it is now known that native iron may also contain nickel. The amount may vary as noted in the nickel content of rocks from contact metamorphic zones. At Ovifak, Greenland, nickel-bearing pyrrhotite was found associated with basaltic lava that had cut a carbon-rich zone and had, therefore, become enriched in carbon. This suggests a process by which iron may have occurred as well as the iron-nickel sulfide, pentlandite $(Fe, Ni)_9S_8$ (Schneiderhoehn, 1955, p. 302).

Iron artifacts described by Alcina Franch (1970) from the Bering Strait are from the Punuk culture (A.D. 500) and those from the eastern United States are from the Hopewell culture (A.D. 500–900). These appear very late in comparison with the 1000 B.C. date for copper production in North America.

[13]The unclear use of *fierro* (iron) and *fierro hematite* (iron hematite) in archaeology has led to similarly unclear interpretations. For example, it has been noted that some of the axes that were fire-hardened were explained as *fundir fierro* (to smelt iron). For whatever reason, this is not how iron was

obtained nor is this the way that iron was produced. There is the implication that simply grinding and heating hematite will result in iron without using the appropriate metallurgy.

[14]There is some confusion in the bibliography about the number of mummies. Root (1949b) describes *dos mineros de cobre* (two copper miners). However, in reality three mummies are known and two of these are in the Museo Nacional de Santiago de Chile; one is from Puchoco and the other is from the Guitecas Islands. These are not related to the third mummy from Chuquicamata which is now in the Museum of Natural History in New York.

[15]The author, Anónimo de Sevilla (1938, p. 324) wrote that "The Chief Atahualpa said that there was little gold at the mines and that the mines of Collao, near Cusco, were much richer. Gold nuggets were plentiful and there was no need to wash the gold, however, gold could also be obtained from the rivers. There are many people at Collao and there is a large river with an island where there are dwellings and between them is a place covered in gold and with straw made of gold. The gold from this area could not be taken using a *batea*. However, gold was taken from the streams that leave this river which washes the earth. I have heard that the grains of gold are plentiful and all the people of the land of Collao that I have questioned say that this is true."

Porras Barrenechea (1937) thinks that "Anonimo" is in reality, Cristóbal de Mena (or Medina) who was one of the five Spaniards, who upon hearing the first reports of gold, left for Spain in June 1533 and arrived in December 1533. He is thought to have published "La Conquista del Perú" in Sevilla in April 1534.

[16]Pedro Pizarro (1571) wrote "…having heard about the richness of Collao from the two Spaniards, Diego de Aguero and Pedro Martínez de Moger, who had been sent there." According to Porras Barrenechea (1937) these two were among the three who had earlier been to Cusco to obtain some of the Atahualpa ransom.

Diego de Aguero (y Sandoval) was one of the Spaniards who played a role in the capture of Atahualpa and he was also was one of the founders of Lima. Pedro Martínez de Moger, also known as Pedro Martín de Moger or Pedro Moger, was one of the soldiers who participated in the capture of Atahualpa and he was also one of the founders of Cusco. He was killed shortly before the Manco uprising by the Sanas Indians (Porras Barrenechea, 1937).

[17]The explorers say that it was approximately one hundred *leguas* (a league may be from 3.9 km to 7.4 km) without giving much other detail and it is unclear if this referred to diameter or circumference. The true dimensions are 180 km, the diameter from northwest to southeast and with a circumference of approximately 950 km.

[18]At the gold fields at Poto-Ananea, gold is recovered hydraulically using monitors that run all night as long as there is sufficient water in the nearby streams. Strong lights are also used to illuminate the mining operations.

[19]Middendorf (1895) explains that the word *puma* when used as an adjective indicates something very large and strong. For example, *pumapunca* is a large door and *pumamarca* indicates a large place.

[20]Aguero and Martínez (Sancho, 1534/1938, p. 180) indicate that "In the middle are two small islands and one of these is the revered Temple of the Sun where offerings and sacrifices are made. There is also a large stone that is called Tichicasa….and offerings of gold, silver, and other things are made. There are more than six hundred people living there and more than one thousand women who make chicha for the sacred stone known as Tichicasa." He does not say precisely whether or not this information was for the same island or possibly for Copacabana or Yunguyo. Squier (1875/1833) gives a detailed description and the sacrificial stone, called Tichicasa, is shown in Middendorf (1895, p. 419).

[21]The preference for laminated and hammered objects is evident at the excavations at Tablada de Lurin where many laminated or embossed artifacts were found. Among these artifacts, only four clubheads were found that were made using the lost wax method (Schwörbel, 1969).

[22]The selection of the ore from the waste is known as *pallaqueo* (*pallay*, to collect) and those who break the mineralized rock are called *chanquiris* (*chankkay*, separate). The women and children who do this work are known as *pallaquiris* and the workplace is known as the *cancha*.

[23]In the ancient world, for example in Egypt, pure gold does not come from the mines. It is in a natural mixture that may include silver, copper, and other metals. The Egyptians, during their early history, refined native gold by using a process that required an uninterrupted distillation process that took five days. The temperature had to be maintained very close to the melting temperature of gold (1063 °C). Lead was used to remove copper, salt was used to remove silver, and straw was used for the reduction of oxidized impurities. The process required great skill so that very little gold was lost which even under normal conditions, could be as much as 5%.

[24]Diccionario Santo Tomás (1650): *chambi*, clubhead; (Ricardo, 1586); González Holguín: *champi*, club for battle.

[25]Root (1949b) discusses the metallurgical problem "Gold and copper are the two components of the gold-copper alloy and are present only below 420 °C and are hard and fragile. If the eutectic mixture (82% gold and 18% copper) is slowly cooled, the hardness will rise to a Brinell hardness of 190. Upon quick cooling the Brinell hardness is 122. With a 50% gold and 50% copper alloy, the product has a Brinell hardness of 80 if cooled quickly and 40 if it is cooled slowly. This indicates that an alloy with more than 20% copper will become hard if it is worked below 420 °C and the other with more than 50% copper remains softer. If the gold-copper alloy is tempered for a long time, the copper at the surface oxidizes and the Cu_2O becomes distributed along the crystals and the metal becomes fragile. If the oxide at the surface is removed in an acidic bath, the color changes from red to yellow by enrichment at the surface and is called *mise en couleur* or depletion gilding." Additional information is given in Root (1959, p. 77, fig. 1, 2).

[26]Rivet and Arsandaux (1946) list *ácido cítrico*, *acetocilla*, *trifolio acético*, *ácido oxálico*, *sal de acedera*, and **Oxalis pubescens** as the plant-derived acids useful for the process "Peruvian gold and silver plating" and using *ácido cítrico* to remove the oxidized copper. Even though *ácido cítrico* works perfectly well, it was not used in Peruvian metallurgy because **Citrus sp**. is not found in Perú. However, the ancient metallurgists had at their disposition, and for the same purpose, other plants such as **Oxalis sp**. which is abundant in the foothills. A sample of **Oxalis sp**. juice, obtained from Isla Las Viejas and donated by Dr. R. Ferreira, Director of the Museo de Historia Natural Javier Prado (Lima), was used to treat corroded artifacts from Yécala (Piura). Within 15 min of application of the juice, the superficial copper was dissolved, leaving a gilded surface.

[27]Compare Loredo's (1958) discussion of the different opinions on the white gold piece from Cusco, with the image of the Moon, which suggests a gold-platinum alloy. Also consider the discussion by Vásquez de Espinoza (1629/1942, Ch. LXXVI. 1513 and 1514).

[28]Root (1949b, p. 214) discusses the characteristics of the silver-copper alloy: "Silver and copper dissolve in one another up to a certain point. The smelted mixture contains alpha and beta phases. At the eutectic temperature of 779 °C, the alpha phase, contains 9% copper and the beta phase contains 8% silver. At ambient temperatures the two components are almost mutually insoluble. The alpha and beta phases are soft; however, the eutectic mixture is hard. Therefore, through rapid cooling a soft metal is produced and slow cooling and tempering below 779 °C gives origin to a harder metal. If the alloy contains 6-72% silver, the metal crystals rich in copper are jacketed by a eutectic composition. The presence of a silver phase and a copper phase gives the metal its characteristic mottled appearance.

An alloy rich in silver and containing 7.5% copper (sterling silver) has a Brinell hardness of 60 and cold hammering increases the hardness to 183. Tempering of the silver-copper alloy, or upon heating, the copper oxidizes (Cu_2O) and is disseminated along the grain thereby making the metal become fragile. If this oxide-covered alloy is placed in an acidic bath, the oxide will dissolve and leave pure silver at the surface. This method of silver-plating is equivalent to *mise en couleur* or "depletion gilding."

[29]Jijón y Caamaño (1922) describe other alloys:

Cu-Fe-Si	Calchaqui
Cu-Fe-Si-Ni-S	Chicama, Salta
Cu-Fe-Si-Al	La Paya (Chile)

[30]In his study of European bronzes, Wiebel (*in* Baessler, 1906) concludes that the bronzes are produced by the unintentional addition of copper and tin and are, therefore, distinctly different than commercial bronzes, the composition

of which is determined by the intentional addition of specific quantities of pure metals. The "hardmetal" and the "bottoms" found in ancient smelters show the possibility of producing bronze by simply smelting cassiterite and copper sulfides.

[31]According to Root (1949b, p. 215), copper and tin constitute a complex system with various phases; alpha, or bronze with low tin content (<16%), is soft, malleable, and has a melting point between 950 °C and 1083 °C. Upon cooling below 525 °C, it changes to delta bronze with 32% tin and becomes hard and fragile. All South American bronzes are alpha type. The hardness of bronze with low tin content can be increased by the addition of tin or by cold-hammering:

	Brinell hardness	
	Smelted	Cold-hammered
Copper	40	–
Bronze (5% tin)	50	200
Bronze (10% tin)	90	275

Bronze with low tin content expands upon solidification. The maximum expansion (0.12%) is obtained with approximately 10% tin. This bronze is smelted at 1005 °C or approximately 80 °C lower than pure copper. The bronze is more fluid than copper at the same temperature and flows more freely. Additional data is available in Foote and Buell (1912).

[32]Lothrop et al. (1959, p. 281) describe: "Mirrors are made as a mosaic using pyrite, turquoise, and shell. The mosaic is mounted on a wooden base cut of only one piece of wood which has been identified as **Belucaceae sp**. This is a type of tree, perhaps an aspen or poplar, that is known in Perú as *aliso* (alder) or *tembran* (a tropical canopy tree). The mosaic pieces are cemented in place using a resin….which is intact and firm below the polished pieces…some of the individual shell pieces show perforations made by marine mollusks. Pyrite mirrors are also known in Mexico, Central America, Panama, Perú, and perhaps other places. The age of these mirrors dates to the Maya Classic period (A.D. 250–A.D. 900); however, they are only rarely found in these regions. Examples of mirrors mounted on a wooden base are known only from Perú and mirrors from humid regions may be mounted on a stone or metal base."

REFERENCES CITED AND OTHER SELECTED REFERENCES

A.A. (Ryan?), 1953, Antiguas herramientas de mineria: El Serrano, Oroya, febrero.

Acosta, José de, 1590 (1954), Historia natural y moral de las Indias: Biblioteca de Autores Españoles, Madrid.

Aguilar Condemarin, Lucio F., 1938, La región aurifera del valle de Poto y su descripción geográfica: Boletín de Minas, Industrias, y Construcciones de la Escuela de Ingenieros, Serie III, I, II, p. 21, Lima.

Aguilar Paez, Rafael, 1586 (1970), Gramática Quechua y vocabulario, Adaptación de la primera edición de la obra de Antonio Ricardo "Arte y Vocabulario en la Lengua General de Perú, llamada Quechua, y en la lengua Española," Lima.

Aguilar Revoredo, Juan Francisco, 1940, Algunos capitulos del curso de geología económica de yacimientos minerales: Boletín de Minas, Industrias, y Construcciones, Escuela de Ingenieros, Serie III, T. 13, Lima.

Ahlfeld, Federico, 1946, Estudio sobre la procedencia de las piedras semipreciosas y las rocas encontradas en las ruinas de Tiahuanaco: Boletín de la Sociedad Geológica del Perú, T. 19, p. 34–44, Lima.

Ahlfeld, Federico, and Muñoz Reyes, Jorge, 1955, Las especies minerales de Bolivia: Editado por el Banco Minero de Bolivia, Bilbao, (Impr. Industrial, S.A.).

Ahlfeld, Federico, and Schneider-Scherbina, Alejandro, 1964, Los yacimientos minerales y de hidrocarburos de Bolivia: Boletin no. 5, Departamento Nacional de Geología, Ministerio de Minas y Petróleo, La Paz.

Alcina Franch, José, 1965, La producción y el uso de metales en la América precolombina: Manual de Arqueología Americana, Madrid, Aguilar S.A.

Alcina Franch, José, 1970, La minería Hispánica e Ibero-Americana: VI Congreso Internacional de Minería, v. I, p. 306–331, León Cátedra de San Isidro.

Alonso Barba, Alvaro, 1640 (1967), Arte de los metales en que se enseña el verdadero beneficio de los de oro y plata por azogue, el modo de fundirlos todos y cómo se han de refiner, y apartar unos de otros: Editorial Potosí, Potosí, Bolivia.

Anónimo de Sevilla, 1534 (1938), La conquista del Perú llamada la Nueva Castilla, La cual tierra por divina voluntad fue maravillosamente conquistada en la felísima ventura del Emperador y Rey, nuestro señor; y por la prudencia y esfuerzo del muy magnífico y valeroso caballero el Capitán Francisco Pizzaro, Gobernador y Adelantado de la Nueva Castilla, y de su hermano Hernando Pizarro, y de sus animosos capitanes y fieles y esforzados compañeros que con él se hallaron: Biblioteca de la Cultura Peruana, Primeria Serie, no 2, París. Ver tambien, Mena (1934).

Antze, Gustav, 1930, Metallarbeiten aus dem nordlichem Peru: Mitteilungen a.d. Museum fur Volkerkunde, Hamburg, XV Hamburg.

Antze, Gustav, 1965, Trabajos en metal en el norte del Perú: Serie, Comentarios del Perú, no. 3, Universidad Nacional Mayor de San Marcos, Lima.

Baessler, Arthur, 1906, Altperuanische Metallgerate: Berlin.

Ball, Sydney H., 1941, The mining of gems and ornamental stones by American Indians: Smithsonian Institution, Bureau of American Ethnology, Anthropological Papers no. 13, Bulletin 128, Washington, D.C.

Bargalló, Modesto, 1955, La mineria y metalurgia en la América española durante la época colonial: México.

Bargalló, Modesto, 1967, La guaira, horno de fundición del antiguo Perú, estudio de las referencias de Cronistas: Minería, Organo del Instituto de Ingenieros de Minas del Perú, no. 79, p. 43–49, Lima.

Bargalló, Modesto, 1969, La amalgamación de los minerales de plata en hispano colonial, con una ofrenda a Alvaro Alonso Barba (por Carlos Prieto): México, Comp. Fundidora de Fierro y Acero de Monterrey.

Behrendt, Gerd, 1960, Estudio sobre la creación de formas del Odocoileus peruvianis, Gray: Pesca y Caza, Ministerio de Agricultura, Dirección de Pesqueria y Caza, no. 10, p. 149–166.

Bellido B., Eleodoro, L. De Montreuil D., and D. Girard P., 1969, Aspectos generales de la Metalogenia del Perú: Ministerio de Energía y Minas, Servicio de Geología y Minería, XI Convencion de Ingenieros de Minas, Lima.

Benavides Caceres, Víctor, 1968, Saline deposits of South America, in Mattox, R.B., et al., eds, Saline Deposits: Geological Society of America Special Paper 88, p. 249–290

Benzoni, Girolamo, 1572 (1962), La historia del Mondo Nuovo: Venecia, 1572, Edic. Fassimilar, Akadem. Druck-und Verlagsanstalt, Graz.

Benzoni, Girolamo, 1572 (1967), La historia del Mundo Nuevo: traducción al castellano por C. Radicati di Primeglio, Universidad Nacional Mayor de San Marcos, Lima.

Bergt, W., 1894, Die Gesteine der Ruinenstate von Tiahuanaco im alten Peru: Abhandlungen der Gesellschaft Isis, p. 35–52, Dresden.

Betanzos, Juan de, 1551 (1880), Suma y narración de los Incas: publicada por M. Jiménez de la Espada, Biblioteca Hispano-Ultramar, Madrid.

Bingham, Hiram, 1930, Machu Picchu, a citadel of the Incas: National Geographic Society, New Haven, Yale University Press.

Bingham, Hiram, 1948, Lost city of the Incas, The story of Machu Picchu and its builders: New York.

Bird, Junius B., 1962, Art and life in old Perú, An exhibition: The American Museum of Natural History, v. 2, p. 147–210.

Boman, Eric, 1908, Antiquetés de la Regíon Andine: Paris, 2 Tomos.

Bonavia, Duccio, 1959, Una pintura mural de Pañamarca, Valle de Nepeña: Arqueológicas no. 5, Publicación del Instituto de Investigaciones Antropológicas, Museo Nacional de Antropología y Arqueología, Lima.

Bonavia, Duccio, 1960, Análisis de los morteros y porras de Aya-Orjo (Ayacucho): Cuadernos del Centro de Estudiantes de Antropología: Universidad Nacional Mayor de San Marcos, v. II, no. 1, p. 22.

Bonavia, Duccio, 1962, Decoraciones murales de la vieja Lima: El Comercio, Diario de la manaña (Suplemento Dominical), Lima, domingo 2 de diciembre, p. 6–7.

Bonavia, Duccio, 1970, Investigaciones en el Mantaro Medio: Revista del Museo Nacional, T. XXXV, p. 211–294, Lima.

Bosworth, T.O., 1922, Geology of the Tertiary and Quaternary periods in the northwest part of Perú: Macmillan and Co., London.

Broggi, Jorge A., 1910, Estudio sobre un granate Colofonita de las proximidades de la hacienda Monterrico en la región de Lima: Boletín de Minas, Industrias y Construcciones, Serie III, T. II, no. 4, p. 61–61, Lima.

Cabrera, Angel, and Yépes, José, 1960, Mamiferos Sud Americanos: Segunda edición, Tomo I, Buenos Aires.

Cabrera La Rosa, Augusto, 1954, Situación actual de la minería del mercurio en el Perú: Minera y Metalurgia, p. 3–12, Madrid.

Cabrera La Rosa, Augusto, and Petersen G., Georg, 1936, Reconocimiento geológico de los yacimientos petrolíferos del Departamento de Puno: Boletín del Cuerpo de Ingenieros de Minas del Perú, no 115, Lima.

Calancha, Antonio de, 1638, Cronica moralizada del orden de San Agustín en el Perú, con sucesos egemplares en esa monarquía: Barcelona.

Caley, Earle R., 1970, Chemical composition of the ancient copper objects of South America: paper read in June 1970 at a meeting held at the Museum of Fine Arts in Boston, manuscript to be published along with other papers presented in 1970.

Caley, Earle R., and Easby, Dudley T., 1959, The smelting of sulfide copper in preconquest Perú: American Antiquity, v. 25, no. 1, p. 59–65, doi: 10.2307/276679.

Campana D., Cristobal, 1939, Chavín y Chimú: Centro de Estudios Arqueológicos de Lambayeque, Edic., Syari, Serie Blanca, Chiclayo.

Cano, Washington, 1933, El Lago Titicaca, el mas alto navegable del mundo: Edi. Moreno, Argentina.

Carranza, Fortunato, 1922, Sinópsis histórico-científico de la industria minera del Perú a través de los períodos incaico y colonial: Lima.

Carranza, Fortunato, 1940, Probable origen de la industria minera en el antiguo Perú: Notas y Conferencias, p. 173, Lima.

Chalón, Pablo Federico, 1882, El arte de construer de los antiguos Peruanos: Anales de la Escuela de Construcciones Civiles y de Minas del Perú, Lima.

Christensen, Ross T., 1951, Preliminary report of excavations in the Piura Valley, Perú: Bulletin of the University Archaeological Society, no. 2, p. 36–53, Brigham Young University, Provo, Utah.

Christensen, Ross T., 1955, Una industria moderna de cerámica en Simbilá, cerca de Piura, Perú, Chimor: Boletin del Museo de Arqueología, Universidad Nacional de Trujillo, Año III, no. 1, Trujillo.

Cieza de Leon, P., 1550 (1924), La crónica general del Perú, Tomo I: Colección Urteaga Romero, Historiadores clásicos del Perú, Tomo VII, Lima.

Clement, Albert, 1938, L'emploi des minerals ferreux dans l'Amérique precolombiene: Revista del Museo Nacional, T. VII, no. 1, p. 131–136, Lima.

Cobo, Bernabé, 1653 (1956), Historia del Nuevo Mundo, 2 vol.: Biblioteca de los Autores Españoles, Madrid.

Dall, William H., 1909, Report on a collection of shells from Perú, with a summary of littoral marine mollusca of the Peruvian zoological province: Proceedings of the United States National Museum, no. 37, Washington, D.C.

Disselhoff, Hans Dietrich, 1969a, Seis fechas radiocarbónicas de Vicús: Verhandlungen des XXXVIII Internationalen Amerikanisten Kongreses, Stuttgart-Munchen, v. I, p. 341–345.

Disselhoff, Hans Dietrich, 1969b, Fruh-Nazca im aussersten Suden Perus, Provincia de Camaná (Dpto. de Arequipa): Verhandlungen des XXXVIII Internationalen Amerikanisten Kongreses, Stuttgart-Munchen, v. I, p. 385–391.

Easby, Dudley T., Jr., 1965, Pre-Hispanic metallurgy and metalworking in the New World: Proceedings of the American Philosophical Society, v. 109, no. 2, p. 89–98.

Eilers, A., 1914, Notes on the occurrence of some of the rarer metals in blister copper: Transactions of the American Institute of Mining Engineering, v. 46, p. 217–218.

Engel, Frederic, 1958, Algunos datos con referencia a los sitios precerámicos de la costa peruana: Arqueológicas no. 3, Publicaciones del Instituto de Investigaciones Antropológicas, Museo Nacional de Antropología y Arqueología, Lima.

Fernandez de Oviedo, Gonzalo, 1526 (1950), Sumario de la historia natural de las Indias: Ed. Fondo de Cultura Económica, México-Buenos Aires.

Fester, Gustavo A., 1962, Copper and copper alloys in ancient Argentina: Philadelphia, University of Pennsylvania Press: Chymia: Annual Studies in the History of Chemistry, v. 8, p. 21–31.

Fester, Gustavo D., and Cruellas, José, 1934, Colorantes de Paracas: Revista del Museo Nacional: Tomo III, no. 1–2, p. 154–156.

Foote, H.W., and Buell, W.H., 1912, The composition, structure, and hardness of some Peruvian bronze axes: American Journal of Science, v. 34, p. 128–132.

Freyre Villafane, Alejandro, 1950, Meteorito de Tambo Quemado: Boletín del Instituto Nacional de Investigación y Fomento Mineros, Año 1, no. 1, p. 141–143, Lima.

Friedensburg, Ferdinand, 1965, Die Bergwirtschaft der Erde: 6a Edición, Vlg. Enke, Stuttgart.

Fung, Rosa, 1969, Artefactos de hueso y caña excavados de la unidad de posición del complejo Chavín en Las Haldas: Boletín de Seminario de Arqueología, Pontificia Universidad Católica del Perú, Instituto Riva Aguero, no. 4, p. 44, Lima.

Garcilaso de la Vega, Inca, 1609 (1941/1943), Los comentarios reales de los Incas: Segunda edición, Colección de Historiadores Clásicos del Perú, Tomo I–III, Lima.

Gastelumendi, Alberto G., 1921, Huancavelica como región productora de mercurio: Anales de Congreso Nacional de la Industria Minera: Tomo II, p. 37–69.

Ginsburg, I.I., 1960, Principles of geochemical prospecting: New York.

Goldschmidt, Víctor M., 1954, Geochemistry: A. Muira, Oxford.

Gonzales de la Rosa, Manuel, 1908, Estudio de las antiguedades peruanas halla das bajo el huano: Revista Histórica, Tomo III, p. 39–45, Lima.

González Holguín, Diego, 1568 (1952), Vocabulario de la lengua general de todo el Perú llamada Quechua o del Inga: Reedición del Instituto de Historia, Imp. Santa María, Lima.

Harth-Terré, Emilio, 1933, Incahuasi, ruinas inkaikas del valle de Lunahuaná: Revista de Museo Nacional: Tomo II, no. 2, p. 101–128.

Hauthal, Rudolf, 1911, Reisen in Bolivien und Peru: Verlag von Duncker und Humboldt, Leipzig.

Helmer, María, 1962, Edelmetalle Peru's in der Kolonialzeit: SAECULUM, Jahrbuch fur Universalgeschichte, Año XIII, no. 3, p. 293–300.

Helms, Anton Z., 1798, Tagebuch einer Reise durch Peru, von Buenos Aires an dem grossen Plataflusse, uber Potosi nach Lima, der Haupstadt das Konigrichs Peru: Ed. Walther, Dresden.

Hesse, Milton von, 1969, Perú, pais con tradición minera: *en* D. Rodriguez Hoyle, La Minería Metálica en la Economía Peruana, Lima.

Hollister, Victor F., 1955, Origin and significance of Chan Chan slags [Procedencia y composición química de las escorias de Chan Chan, Chimor]: Boletín del Museo Arqueológico de la Universidad Nacional de Trujillo, año III, no. 1, p 34–39, Trujillo, (diciembre).

Holm, Olaf, 1969, Dientes de tiburon, el utensilio prehistórico y un comentario folklórico: Ed. Casa de la Cultura Ecuatoriana, Nucleo de Guayas, Guyaquil.

Holstein, Otto, 1927, Chan Chan, capital of the great Chimú: National Geographic Magazine.

Horkheimer, Hans H., 1960, Nahrung und Nahrungsgewinnung im vorspanischen Peru: Bibliotheca Ibero-Americana, no. 2, Colloqium Verlag, Berlin.

Horta, S.A., ed., s.f., Diccionario Hispánico Universal: Barcelona.

Humboldt, Alexander von, 1810, Pittoreske Ansichten der Kordilleren un Monumente amerikanischer: Volker, p. 2, p. 88–89, Tubingen, Cota Buchh.

Humboldt, Alexander von, 1829, Ueber die geographischen und geognostischen Arbeiten des Herrn Pentland im sudlichen Peru: Hertha, Zeitschr. f. Erd-Volker-und Staatenkunde Ano 5, p. 1–29, Stuttgart.

Humboldt, Alexander von, 1849, Ansichten der Natur: 2 Tomos, Verl. Cotta, Stuttgart und Tubingen.

Humboldt, Alexander von, 1876, Cuadros de la Naturaleza: Madrid.

Hutchinson, Thomas S., 1873, Two years in Perú with exploration of its antiquities: 2 vol., London.

Iribarren Charlin, José, 1962, Minas de exploitación por los Incas y otros yacimientos arqueológicos en la zona de Almirante Latorre, Departamento de la Serena: Publicación del Museo y la Sociedad Arqueológica de la Serena, Boletin no. 12, p. 61–72, La Serena.

Ibarra Grasso, Dick Edgar, 1960, Una tentativa de fundición del hierro en los valles de Bolivia de hace unos 2000 anos: Zeitschrift fur Ethnologie, v. 85, no. 2, p. 252–258.

Jerez, Francisco de, 1534/1938, Verdadera relación de la conquista del Perú y Provincia del Cuzco, llamada la Nueva Castilla: Biblioteca de Cultura Peruana, Primera Serie, no. 2, Paris.

Jijón y Caamaño, Jacinto, 1922, La edad de bronce en América del Sur: Boletin de la Academia Nacional de Historia, v. IV, no. 9.

Jiménez, Carlos P., 1924, Reseña histórica de la mineria en el Perú: *en* Síntesis de la Minería Peruana en el Centenario de Ayacucho: Tomo I, p. 3–71.

Juan, Jorge, and de Ulloa, Antonio, 1751, Reise nach Sud-Amerika Allgemeine Historie der Reisen zu Wasser un Lande. Sammlung aller reisebeschreibungen, Tome IX, Leipzig.

Kidder, Alfred, II, 1943, Some early sites in the northern Titicaca Basin: Papers of the Peabody Museum of American Archaeology and Ethnology, Harvard University, v. 27, no. 1, Cambridge, Mass.

Kiilsgaard, Thor H., and Bellido, Eleodoro, 1959, Los recursos minerales: Plan regional para el desarrollo del Sur del Perú, v. II, PS/A.5, Lima.

Klaproth, Martin Heinrich, 1804, Chemische Untersuchungen der Pacos aus Peru: CXVII Beitrage zur chemischen Kenntnis der Mineralkorper, tomo 4, p. 4–10, *en* Leonhard's Mineralogisches Taschenbuch: Tomo, v. III, p. 308.

Klockmann, F., and Ramdohr, Paul, 1947, Tratado de mineralogía: Barcelona.

Koepcke, Hans-Wilhelm y Maria, 1951, División ecológica de la costa Peruana: Ministerio de Agricultura, Dirección de Pesquería y Caza, Serie de Divulgación Científica no. 3, Lima.

Kostrinsky, León, 1955, Hallazgos arqueológicos que demuestran la existencia de un antiquisimo pueblo pescador: Pesca y Caza, Ministerio de Agricultura, Dirección de Pesqueria y Caza, no. 6, p. 51–59, Lima.

Kroeber, Alfred Lovis, 1930, Peruvian archaeology: Viking Fund, Publication in Anthropology no. 4, New York.

Kroeber, Alfred Lovis, 1944, Archaeological explorations in Perú: Field Museum of Natural History, Chicago.

Kubler, Georg, 1948, Towards absolute time, guano archaeology, *in* Bennett, W.C., ed., A Reappraisal of Peruvian Archaeology, Society for American Archaeology and Institute of Andean Research, Memoirs of the Society for American Archaeology, v. 4, p. 29–50.

Kunike, Hugo, 1923, El jaguar y la luna en la mitologia de la altiplanicie andina: Inca, Revista Trimestral de Estudios Antropológos, v. I, no. 3, Lima.

Ladd, Harry S., 1957, Treatise on marine ecology and paleoecology: v. 2, Geological Society of America, Memoir 67.

Lanning, Edward P., 1967, Perú before the Incas: Prentice-Hall, Inc., Englewood Cliffs, New Jersey, USA.

Lanning, Edward P., and Hammel, Eugene A., 1961, Early lithic industries of western South America: American Antiquity, v. 27, no. 2, doi: 10.2307/277831.

Larco Hoyle, Rafael, 1941, Los Cupisniques: Casa Edit. La Crónica, Lima.

Larco Hoyle, Rafael, 1945a, Los Cupisniques: Sociedad Geográfica America, Buenos Aires.

Larco Hoyle, Rafael, 1945b, Los Mochicas (pre-Chimú o Early Chimú): Sociedad Geográfica Americana, Buenos Aires.

Larco Hoyle, Rafael, 1945c, La cultura Virú: Sociedad Geográfica Americana, Buenos Aires.

Larco Hoyle, Rafael, 1963, Las épocas peruanas: Lima.

Latcham, Ricardo E., 1927, Tembeta hallada en una sepultura indigena chilena: Revista Chilena de Historia Natural: Año XXXI, p. 38–40.

Latcham, Ricardo E., 1936, Metalurgia Atacameña, objectos de bronce y cobre: Boletín del Museo Nacional: Tomo XV, p. 107.

Lechtman, Heather, 1970, A new understanding of metal gilding techniques in pre-Columbian Perú: XXXIX Congreso Internacional de Americanistas, Resumen de Ponencias, 2–9 de agosto, Lima.

Lewis, Richard W., 1956, Geology and mineralogy of the Castrovirreyna District, Huancavelica: Boletín de la Sociedad Geológica del Perú: Tomo 30, p. 217–224.

Lieber, W., 1969, Mineralogie in Stichworten: Edit. Hirth, Kiel.

Lira, Jorge A., 1945, Diccionario Kkechuwa-Español: Universidad Nacional de Tucumán, Departamento de Investigaciones Regionales, Instituto de Historia, Linguistica y Folklore, XII, Tucumán.

Lizarraga, Fray Reginaldo de, 1602? (1908), Descripción y población de las Indias: Revista del Instituto Histórico del Perú, p. VII + 209, Lima.

Lohmann Villena, Guillermo, 1949, Las minas de Huancavelica en los siglos XVI–XVII: Publicación de la Escuela de Estudios Hispano-Americanos de Sevilla, Serie 2, no. 14, Sevilla.

López de Gómara, Francisco, 1552 (1954), Historia general de las Indias: 2 Tomos, Serie Obras Maestras, Barcelona.

Loredo, Rafael, 1958, Los repartos: Bocetos Para la Nueva Historia del Perú, Lima.

Lothrop, Samuel Kirkland, 1941, Gold ornaments of Chavín style from Chongoyape, Perú: American Antiquity, v. 6, no. 3, p. 250–262, doi: 10.2307/275542.

Lothrop, Samuel Kirkland, 1950, Metalworking tools from the central coast of Perú: American Antiquity, v. 16, no. 2, p. 160–161, doi: 10.2307/276894.

Lothrop, Samuel Kirkland, 1953, La metalurgía aborigen de América: Letras, Organo de la Facultad de Letras de la Universidad Nacional Mayor de San Marcos, no. 49, p. 83, Lima.

Lothrop, Samuel Kirkland, 1954, A Peruvian goldsmith's grave: Archaeology, v. 7, p. 31–36.

Lothrop, Samuel Kirkland, 1955, Tumba de un orfebre Peruano: Revista del Museo Nacional de Antropología y Arqueología, v. II, no. 2, p. 146–150.

Lothrop, Samuel Kirkland, 1964, El tesoro del Inca, según fue visto por los historiadores Españoles: Comentarios del Perú no. 1, Universidad Nacional Mayor de San Marcos, Lima.

Lothrop, Samuel K., Foshay, W.F., and Mahler, J., 1959, Robert Woods Bliss Collection, Pre-Columbian Art: Phaidon Press, London.

Lumbreras Salcedo, Luis G., 1969, De los pueblos, culturas, y las artes del antiguo Perú: Moncloa-Campodónico, ed., 306 p., Lima.

Lynch, T.F., and Kennedy, K.A.R., 1970, Early human cultural and skeletal remains from Guitarrero Cave, northern Perú: Science, v. 169, p. 1307–1309, doi: 10.1126/science.169.3952.1307.

MacNeish, R.S., Berger, R., and Protsch, R., 1970, Megafauna and man from Ayacucho, Highland Perú: Science, v. 168, p. 975–977, doi: 10.1126/science.168.3934.975.

MacNeish, R.S., Berger, R., and Protsch, R., 1971, Early man in the Andes: Scientific American, v. 224, no. 4, p. 36–46.

Marshall, George, 1964, Notes on the examination of some pre-Columbian metal samples [Examen de algunas muestras pre-Colombinas de metal]: Arqueológicas, no. 7, Publicación del Instituto de Investigaciones Antropológicas, Museo Nacional de Antropología y Arqueología, 18 p., Lima.

Mead, Charles W., 1901, La momia de Chuquicamata: Revista Nueva, p. 144–154, Santiago de Chile.

Mead, Charles W., 1915, Prehistoric bronze in South America: Anthropological Papers of the American Museum of Natural History, v. XII, part II.

Medina, José Toribio, 1952, Los aborigenes de Chile: p. 431, Santiago de Chile.

Meggers, Betty J., 1966, Ecuador, ancient peoples and places: Thames and Hudson, London.

Mejia Xesspe, Toribio, 1931, Kausay, alimentacion de los indios: Wira Kocha, Tomo I, no. I, p. 9–24, Lima.

Mena, Cristóbal de, 1534, see Anónimo de Sevilla.

Middendorf, Ernest W., 1890, Worterbuch des runa simi oder der Keshuasprache: F.A. Brockhaus, Leipzig.

Middendorf, Ernest W., 1893–1895, Peru, beobachtungen und studien uber das land und seine bewohner. Vol. I: Lima, Berlin, 1893. Vol. II: Das Kustenland, Berlin, 1894. Vol. III: Das Hochland, Berlin, 1895.

Mille, M., and Ponce Sanginés, Carlos, 1968, Las andesitas de Tiwanaku: Academia Nacional de Ciencias de Bolivia, Publicación no. 18, La Paz, 18 p.

Miller, B.L., and Singewald, J.T., Jr., 1919, The mineral deposits of South America: New York.

Molina, Wenceslao, 1891, Apuntes sobre la región aurífera de Poto: Tesis, Universidad Nacional de Ingeniería, Lima. 75 p.

Morúa, Fr. Martín de, 1925, Historia de los Incas, reyes de Perú: Colección de Libros y Documentos Referentes a la Historia del Perú, Tomo V, (2da. Serie), Imp. Sanmarti y Cia., Lima.

Muelle, Jorge C., 1940, Espejos precolombinos del Perú: Revista del Museo Nacional: Tomo, v. IX, no. 1, p. 5.

Muelle, Jorge C., 1957, Puntas de pizarras pulidas: Arqueológicas no. 12, Publicación del Instituto de Investigaciones Antropológicas, Museo Nacional de Antropología y Arqueología, Lima.

Muelle, Jorge C., 1963, Tecnología del barro en el Perú precolombino, *en* Bosch, A.P., En el septuagésimo aniversario de su nacimiento, p. 327–330, Mexico.

Muelle, Jorge C., 1965, Sala de oro: Guías de Museo Nacional de Antropología y Arqueología, Lima, 18 p.

Muelle, Jorge C., and Wells, Robert, 1939, Las pinturas del templo de Pachacamac: Revista del Museo Nacional: Tomo 8, no. 2, p. 265.

Mujica Gallo, Miguel, 1959, Gold in Perú: Meisterwerke der Goldschmiedekunst aus der Pra-Inka-zeit, dem Inkareich und der Uebergangsara, Einleitung von Raul Porras Barrenechea, Recklinghausen, Aurel Bongers, Berlin, 298 p., 144 láminas.

Mujica Gallo, Miguel, 1968, Catálogo: Museo Oro del Perú, Lima.

Newell, Norman D., 1949, Geology of the Lake Titicaca region, Perú and Bolivia: The Geological Society of America Memoir 36, New York.

Nomland, Gladys A., 1939, New archaeological site at San Blas, Junin, Perú: Revista del Museo Nacional: Tomo VIII, no. 1, p. 61–66.

Olaechea, Teodorico, 1887, Apuntes sobre el Departamento de Apurímac: Anales de Construcciones Civiles y de Minas, Tomo VI, Lima.

Olaechea, Teodorico, 1901, Apuntes sobre el Castillo y fundición de Curamba: Anales de Ingenieros de Construcción Civil de Minas e Industria del Perú: Tomo 6, p. 1–21.

Olsson, Axel A., 1961, Mollusks of the tropical Eastern Pacific, particularly from the southern half of the Panama-Perú faunal province: Paleontological Research Institution, Ithaca, New York.

Panizo, José Vincent, 1934, La región del valle del Río Chinchipe: Boletín Oficial de la Dirección de Industrias: Tomo XIII–XIV, p. 61–71.

Pardo, Luis A., 1942, Sillustani, una metropólis Incaica: Revista de Museo Nacional: Tomo XI, p. 203–215.

Paz Soldán, Mariano Felipe, 1877, Diccionario geográfico estadistico del Perú: Imp. del Estado, Lima.

Petersen G., Georg, 1932, La exploitación industrial de yacimientos de oro en el valle del Río Tambopata, Perú: Boletín de Minas, v. III, no. 4, Lima.

Petersen G., Georg, 1955, Adorno labial de oro usado por los Tallanes: Revista del Museo Nacional de Antropología y Arqueología, v. II, no. 2, Lima.

Petersen G., Georg, 1960, Sobre Condoriquiña y otros depósitos de estaño en el Perú: Boletín de la Sociedad Nacional de Minería y Petróleo, v. II, no. 72, p. 36–44, Lima.

Petersen G., Georg, 1964, Sobre los depósitos aluviales auríferous del Río Tumbes: Boletín de la Sociedad Nacional de Minería y Petróleo, no. 99, p. 11–13, setiembre-octubre, Lima.

Petersen G., Georg, 1965, Ilustraciones geológicas para los cursos de geología general y economica: Segunda Edición, 40 p., Lima.

Petersen G., Georg, 1969a, Apreciación geológica de objects arqueológicos de Yécala, Vicús, Departamento de Piura: Tecnia, Publicación de la Universidad Nacional de Ingeniería, no. 2, p. 56–77, febrero, Lima.

Petersen G., Georg, 1969b, Algunas notas históricas sobre la minería en el Perú, periodo prehistórico: Algunos Aspectos de Técnica Minera del Perú, XI, Convención de Ingenieros de Minas del Perú, Sección Reseña Histórica, p. 1–6, Lima.

Petersen G., Georg, 1970, Mineria: Organo del Instituto de Ingenieros de Minas del Perú, n. 101, p. 174–178, Lima.

Perroud, Pedro Clemente, and Chouvenc, Juan María, 1970, Diccionario Castellano Kechwa-Kechwa Castellano: Seminario San Alfonso, Padres Redentoristas, Lima.

Pezzia, Assereto Alejandro, 1970, Guía del mapa arqueológico pictográfico del Departamento de Ica: Lima.

Philipsborn, Hellmut von, 1967, Tafeln zum bestimmen der minerale nach ausseren kennzeichen: 2a edición, Edit. Schweitzerbart, Stuttgart.

Pilsbry, Hellmut A., and Olson, Axel A., 1941, A Pliocene fauna from western Ecuador: The Academy of Natural Sciences of Philadelphia, v. XCIII, Philadelphia.

Pizzaro, Pedro, 1571, 1968, Relación del descubrimiento y conquista de los reinos del Perú: Biblioteca Peruana, El Perú a Través de los Siglos: Primera Serie, v. I, p. 441–586.

Polo, José Toribio, 1911, Reseña histórica de la minería en el Perú: Lima.

Ponce Sanginés, Carlos, 1970, Wankarani y Chiripa y su relación con Tiwanaku: Academia Nacional de Ciencias de Bolivia, Publicación no. 25, 79 p., La Paz.

Porras Barrenechea, Raúl, 1937, Las relaciones primitivas de la conquista del Perú: Cuadernos de la Historia del Perú, Serie: Los Cronistas de la Conquista, París.

Posnansky, Arthur, 1945 (1957), Tiahuanaco, la cuna del hombre Americano: 4 Tomos en 2 volúmenes, Tomo I y II, New York, 1945 y Tomo III y IV, Ministerio de Educación, La Paz, 1957.

Quiring, Heinrich, 1962, Platinmetalle (Platin, Palladium, Iridium, Osmium, Rhodium, Ruthenium): Die Metallischen Rohstoffe, Bd. 16., Stuttgart.

Raimondi, Antonio, 1878, Minerales del Perú o catálogo razonado de una colección que representa los principales tipos minerales de la República: Lima.

Raimondi, Antonio, 1879, El Perú: Tomo III, Historia de la Geografia del Perú, Libro Segundo, Lima.

Raimondi, Antonio, 1887, Minas de Oro del Perú: Lima, Imprenta y Libreria de B. Gil.

Raimondi, Antonio, 1939, Minerales del Perú: Tomo II, Lima.

Raimondi, Antonio, 1944, El oro del Perú: La Minería Peruana, no. 26, p. 19, Lima.

Ramdohr, P., 1969, The ore minerals and their intergrowths: 3a. edición organizado por Chr. Amstutz, Pergamon Press, Oxford-Braunschweig.

Ramusio, Gio Battista, 1545?, Navigazione e viaggi racolto de M. Gio Battista Ramusio: en Venetia nell Sampelia de Giunti MDLXV, (Citado: Valcárcel, 1935a).

Ravines, Rogger, 1970, 100 años de arqueología en el Perú: Edición de Petróleos del Perú, Serie: Fuentes e Investigaciones para la Historia de Perú, 406 p., Lima.

Reiss, Johann Wilhelm, and Stübel, Moritz Afonso, 1880 (1887), Das totenfeld von Ancon (The necropolis of Ancon in Perú): 3° vol., Berlin.

Ricardo, Antonio (P. Alonso de Barsana?), 1586 (1951), Vocabulario y phrasis en la lengua general de los indios del Perú, llamada Quichua y en la lengua Española: El mas copioso hasta agora se ha impresso. En los Reyes. Por Antonio Ricardo, año 1586, quinta edición publicada con un prólogo y notas de Guillermo Escobar Risco, Edición del Instituto de Historia de la Facultad de Letras, Universidad Nacional Mayor de San Marcos, Lima.

Rivera Plaza, G., 1944, Colección Mineralógica Nacional, Museo Mineralógico de la Escuela Nacional de Ingenieros: Boletín de la Escuela Nacional de Ingenieros: Serie III, no. 17, p. 131.

Rivera Plaza, G., 1947, Nomenclatura mineralógica y glosario de términos mineros: Boletín de la Escuela Nacional de Ingenieros, Tomo XX, julio-setiembre y octubre-diciembre.

Rivet, Paul, and Arsandaux, H., 1946, La métallurgie en Amérique précolombienne: Travaux et Mémoires de l'Institut d'Ethnologie, v. 39, 116 p., París.

Rivero y Ustariz, Mariano Eduardo, 1857, Exploitación del guano en tiempo prehistórico: Colección de Memorias Científicas: Agrícolas e Industriales, v. 1, p. 159.

Rivero, Mariano Eduardo, and Tschudi, J.J., 1851, Antiguedades Peruanas: Viena.

Rivero, Mariano Eduardo, and Tschudi, J.J., 1853, Peruvian antiquities: New York.

Romaña, Eduardo, 1908, Una inspección de los yacimientos de estaño de Bolivia y una exploración por el mismo metal en el Perú: Boletín del Cuerpo de Ingenieros del Perú, no. 57, Lima.

Root, William, 1949a, Metallurgy: Handbook of South American Indians, J.M. Steward, ed., v. 5, p. 204, Washington.

Root, William, 1949b, The metallurgy of the southern coast of Perú: American Antiquity, v. 15, no. 1, p. 10–37, doi: 10.2307/276954.

Root, William , 1959, Gold copper alloys in ancient America: Journal of Chemical Education, v. 28, no. 2, p. 76–78.

Rowe, John Howland, 1946, Inca culture at the time of the Spanish conquest: Handbook of South American Indians, v. 2, p. 183–330, Washington.

R.R., 1894, Antiguo método de tratamiento del plomo argentífero en el Perú: Boletín de Minas, Industrias, y Construcciones, v. X, no. 1, p. 7.

Ryden, Stig, 1947, Archaeological research in the highlands of Bolivia: Goteborg.

Saenz, Nicolás A., 1892, Artes e Industrias del Perú antiguo, I. Instrumentos Incaicos: Boletín de Minas, Industrias, y Construcciones, año VIII, no. X, octubre 31, p. 76, Lima.

Sancho de la Hoz, Pedro, 1534 (1938), Relación para SM. de lo sucedido en la conquista y pacificación de estas provincias de la Nueva Castilla y de la calidad de la tierra: Biblioteca Cultura Peruana, I, Serie, no. 2, Los Cronistas de la Conquista, París.

Santa Cruz, Pachacuti Juan, 1927, Los indigenas del norte de Chile antes de la conquista de los españoles: Revista Histórica y geográfica, Tomo VII, no. 71.

Santo Tomas, Fray Domingo de, 1560 (1951), Gramática o arte de la lengua general de los indios de los reynos del Perú: Edición fascimilar publicada con un prólogo por R. Porras Barrenechea, Lima.

Schaedel, Richard P., 1951, Mochica murals at Pañamarca, Perú: Archaeology: Tomo IV, no. 3, p. 145.

Schmidt, Max, 1929, Kunst un kultur von Peru: Berlin.

Schnapka, Adolfo, 1962, Das silberbergwerk Caylloma in Peru: Berg-und Huttenmannische Monatshefte, 107 Jg. 1, p. 12–18.

Schneiderhoehn, Hans, 1955, Erzlagerstaten: Verlag-Fischer, Stuttgart.

Schwörbel H., Gabriela, 1969, Armas de cobre en la necropólis de Lurín: Boletín de Seminario de Arqueología, Pontificia Universidad Católica del Perú: Instituto Riva Aguero, v. I, no. 3, p. 46.

Seeler, E., 1893, Peruanische altertumer des Konigl: Museums zu Berlin, Berlin.

Solari, M.E., 1967, La minería prehistórica de Chile: Minería, Organo del Insituto de Minas del Perú, no. 79, p. 51, Lima.

Solorzano Pereira, Juan de, 1647, Política Indiana.

Squier, Ephrain George, 1878, Perú, incidents of travel and exploration of the land of the Incas: London.

Steffen, Max, 1883, Die landwirtschaft bei den altamerikanischen kulturvolkern: Leipzig.

Steinmann, Gustavo, 1929 (1930), Geologie von Peru: Heidelberg.

Stiglich, Germán, 1922, Diccionario geográfico del Perú: Torres Aguirre, Lima.

Strong, William Duncan, 1957, Paracas, Nazca, and Tiahuanacoid cultural relationships in south coastal Perú: Memoirs of the Society for American Archaeology, no. 13, Salt Lake City.

Stumer, Louis H., 1954, The Chillón Valley of Perú, excavation and reconnaissance 1952–1953: Archaeology, v. 7, no. 4, p. 220–228.

Suter, Hans, 1927, Einige bemerkungen uber die stratigraphische stellung der peruanischen Tablazo Formation: Centralblatt fur Mineralogie, p. 269–277, Berlin.

Tafur H., Issac A., 1950, Nota preliminar de la geología del valle de Cajamarca, Perú: Tesis para optar el grado de Doctor en Ciencias Geológicas, en la Facultad de Ciencias de la Universidad Nacional Mayor de San Marcos, Lima.

Tello, Julio C., 1923, Wira Kocha: Inca, Revista Trimestral de Estudios Antropológicos del Museo de Arqueología de la Universidad Nacional Mayor de San Marcos, v. 1, no. 1 y v. I, no. 3, Lima.

Tello, Julio C., 1929, Antiguo Perú: Primera Epoca, Lima.

Tello, Julio C., 1937, El strombus en el arte Chavín: Edit. Antena, Lima.

Tello, Julio C., 1940, Vaso de piedra de Nazca, primeros indicios de una cultura megalítica semejante a la de Chavín en la región central del Perú: Chasqui, v. I, no. I.

Torres Rubio, Diego de, 1616 (1966), Arte de la lengua Aymara: Actualización de Mario Franco Inojosa, Lima.

Trimborn, Hermann, 1948, Vergessene konigreiche. Kulturgeschichtliche Forschungen. Bd. 2. Braunschweig.

Trimborn, Hermann, 1959, Archaelogische studien in den kordilleren Boliviens: Baessler Archiv. Beitrage zur Volkerkunde. N.F. Beiheft 2. Dietrich Reimer, Berlin.

Trimborn, Hermann, 1961, Die religionen der volkerschaften des sudlichen Mittelamerika und des nordlichen und mittleren Andenraumes: Die Religionen des Alten Amerika, p. 127–170. Bd. 7. Die Religionen der Menschheit. W. Kohlhammer, Stuttgart.

Trujillo, Diego de, 1948, Relación del descubrimiento del reyno del Perú: Publicaciones Escuela de Estudios Hispano-Americanos de Sevilla XLVIII, serie 7, no. 4, Sevilla.

Tschopik, Harry, Jr., 1946, The Aymara: Handbook of South American Indians, *in* Steward, J.H., ed.: Washington, D.C., Smithsonian Institution, Bureau of American Ethnology, v. 2, p. 501–520.

Tschudi, Juan Jacob von, 1891, Kulturhistorische und sprachliche beitrage zur Kenninis des alten Peru: Denkschriften der Kais. Akad. Der Wissenschaften, Wien, Tomo XXXIX, F. Tempsky, Wien.

Uhle, Max, 1908, Pachacamac: Philadelphia, University of Pennsylvania, Department of Archaeology.

Valcárcel, Luis E., 1932, El gato de agua, sus representaciones en Pucurá y Nazca: Revista del Museo Nacional: Tomo I, no. 2, p. 3–27.

Valcárcel, Luis E., 1933, Esculturas de Piquillajta: Revista del Museo Nacional, Tomo II, no. 1, Lima.

Vásquez de Espinoza, Antonio, 1628 (1942a), Compendium and description of the West Indies [translation by C. Upson Clark]: Smithsonian Miscellaneous Collection, v. 102, Washington, D.C.

Vásquez de Espinoza, Antonio, 1628 (1942b), Compendio y descripción de las Indias Occidentales: Smithsonian Miscellaneous Collection, v. 108, Washington.

Vasquez, Emilio, 1937, Sillustani, una metropóli pre-Incaica: Revista del Museo Nacional: Tomo VI, no. 2, p. 278–290.

Velasco, Juan, 1840, Historia del reino de Quito en la América meridional: Quito.

Villar Córdova, Pedro Eduardo, 1935, Las culturas prehispanicas del Departamento de Lima: Primera edición, Homenaje al IV Centenario de la Fundación de Lima o "Antigua Ciudad de los Reyes," Lima.

Villar, Leonardo, 1887, Lexicologia Keshua: Uirakocha, Imprenta El Comercio, Lima.

Wendt, Arthur F., 1890, Las minas de Bolivia: Boletín de Minas, Industrias y Construcciones, Tomo VI, no. 1, p. 4–5, 25 de enero, Lima.

Wetzel, Otto, 1939, Artefactos de silex de Punta Sal, provincia de Tumbes, Perú y Chitinodendron peruanum, sp.: Boletín Oficial de la Dirección de Minas y Petróleo, año XVIII, no. 59–60, junio, Lima.

Wiebel?, (undated), Die kultur der bronzeit nord und mitteleuropas: XXII Bericht der Schleswig-Holstein-Lauenburger Gesellschaft fur Sammlung und Erhaltung vaterlandischer Altertumer. (Citado por Baessler, 1906?).

Wiener, Charles, 1880, Perú et Bolivie, récit de voyage: Hachette et Cie., Paris.

Wissler, Clark, 1938, The American Indian, an introduction to the anthropology of the new world: Oxford University Press, New York.

Wolf, Teodoro, 1879, Viajes científicos por la República del Ecuador: Memorias sobre la geografía y geología de la provincia de Esmeraldas, Empr. del Comercio, Guayaquil.

Wolf, Teodoro, 1892, Geografía y geología del Ecuador: Leipzig.

Yacovleff, Eugenio, and Muelle, Jorge C., 1934, Notas al trabajo colorantes de Paracas: Revista del Museo Nacional: Tomo III, no. 1-2, p. 157.

Zarate, Augustin de, 1555 (1944), Historia del descubrimiento y conquísta del Perú: Lima.

Zevallos Quiñones, Jorge, 1947, Un diccionario Castellano-Yunga: Estudios Yungas III, Imprenta del Ministerio de Educación Pública, Lima.

Figure 1. Hand-picking quartz, which contains visible gold, to be crushed in a manual stone mill, or *quimbalete*, Rinconada San Francisco, elevation of more than 5000 m, extreme northwest of Nevado Ananea, Prov. Sandia, Dept. Puno. (Photograph by G. Petersen G., 30 April 1945.)

Figure 2. Manual stone mill, or *quimbalete*, used to crush gold-bearing quartz at Rinconada San Francisco, elevation of more than 5000 m, extreme northwest of Nevado Ananea, Prov. Sandia, Dept. Puno. (Photograph by G. Petersen G., 30 April 1945.)

Figure 3. Vein of gold-bearing quartz in Ordovician phyllites, in local production (see Figs. 1 and 2) and exposed by glacial retreat, Rinconada San Francisco, elevation of more than 5000 m, Prov. Sandia, Dept. Puno. (Photograph by G. Petersen G., 30 April 1945.)

Figure 4. Ancient adit in a glaciofluvial gold deposit at Llenqueni, Rio Tambopata, Prov. Sandia, Dept. Puno. (Photograph by G. Petersen G., 23 September 1932.)

Figure 5. Alluvial gold prospecting at Pampa Blanca, Prov. Sandia, Dept. Puno, elevation of 4800 m. To the right are the gravels that comprise the alluvial gold occurrence and the gold is washed in the canal using glacial meltwater that comes from Nevado Ananea (5835 m). In the distance to the left is Pampa Blanca and in the center is Laguna Sillacunca, which supplies water to the artisanal gold miners at Poto. (Photograph by G. Petersen G., 29 March 1945.)

Figure 6. Native copper from the Cerro de Pasco mine, from the Museo Geológico de la Universidad Nacional de Ingeniería, Lima. (Photograph by Prof. F. Corante.)

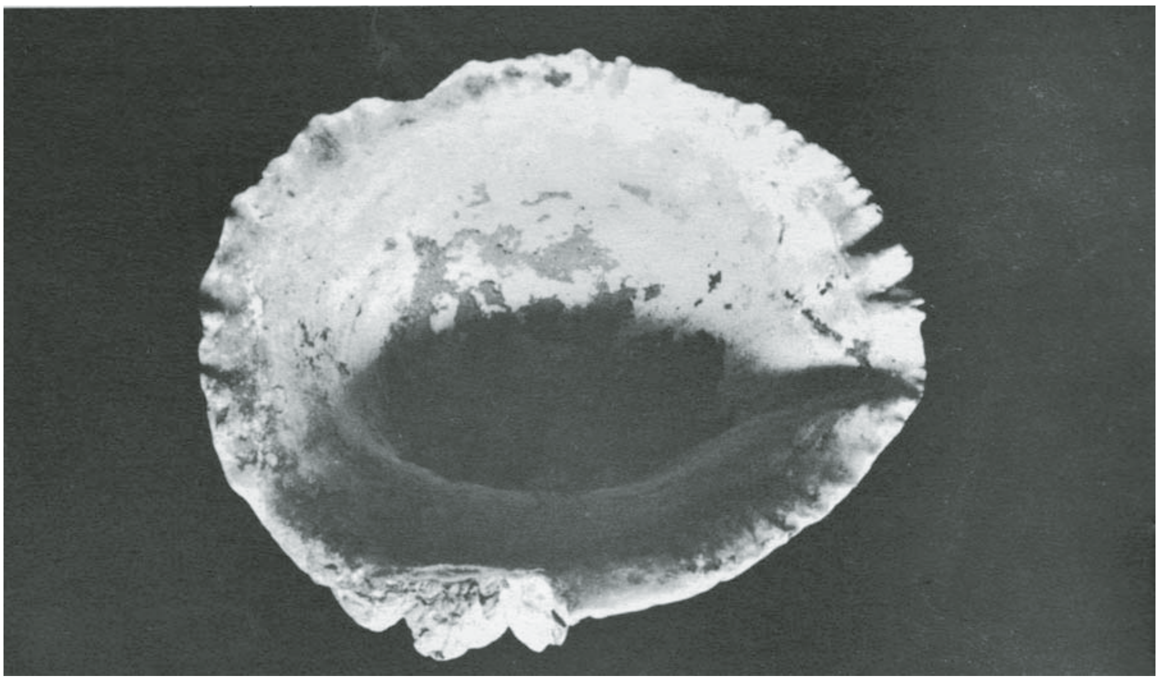

Figure 7. **Concholepas concholepas bruguiere** or *pata de burro*, a bivalve shell from the southern coast of Perú that was used for paints and this example has some cinnabar paint remaining on the inside. This is from a pre-Columbian tomb that is 2 km north of Ocucaje, Ica. (Photograph by Prof. F. Corante, 1970.)

Figure 8. Pisac ruins at Cusco which were constructed using building blocks that were finished only on the exterior surface (see Chapter 1). (Photograph by Prof. F. Corante, 1970.)

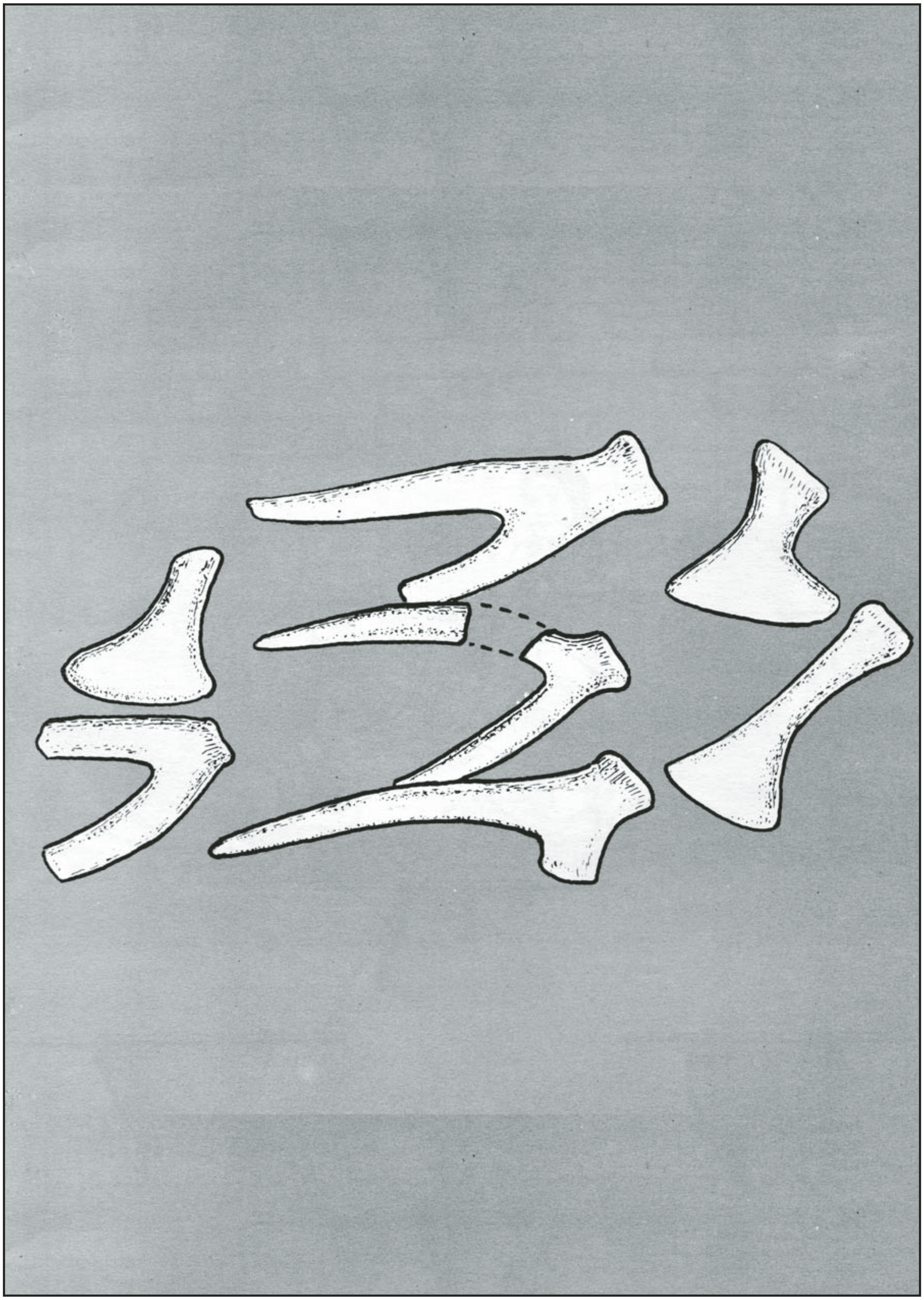

Figure 9. Ancient mining tools made of hardened *taruca* antler, found at the Yauricocha mine, Cerro de Pasco. Drawn from a photograph by A.A. (Ryan?) that appeared in El Serrano newspaper. Permission from the Cerro de Pasco Corporation, February 1953.

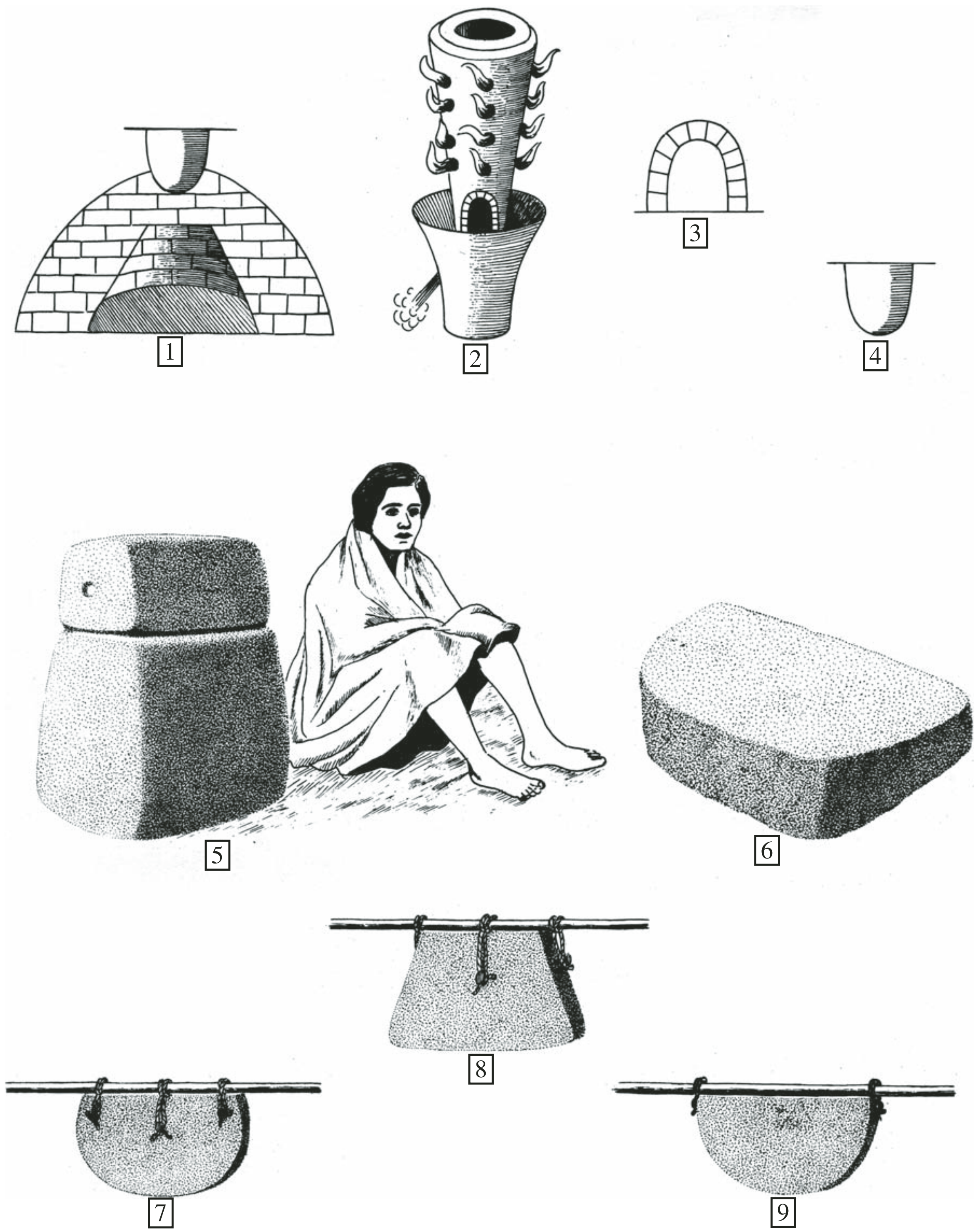

Figure 10. Ancient mining and metallurgical tools. (1, 3, and 4) Various ovens for refining silver. (2) Portable *huayra* or *guaira* for smelting silver. (5–9) Hand stone crushers or *quimbaletes*. (A. Alonso Barba, 1640, Arte de los Metales.)

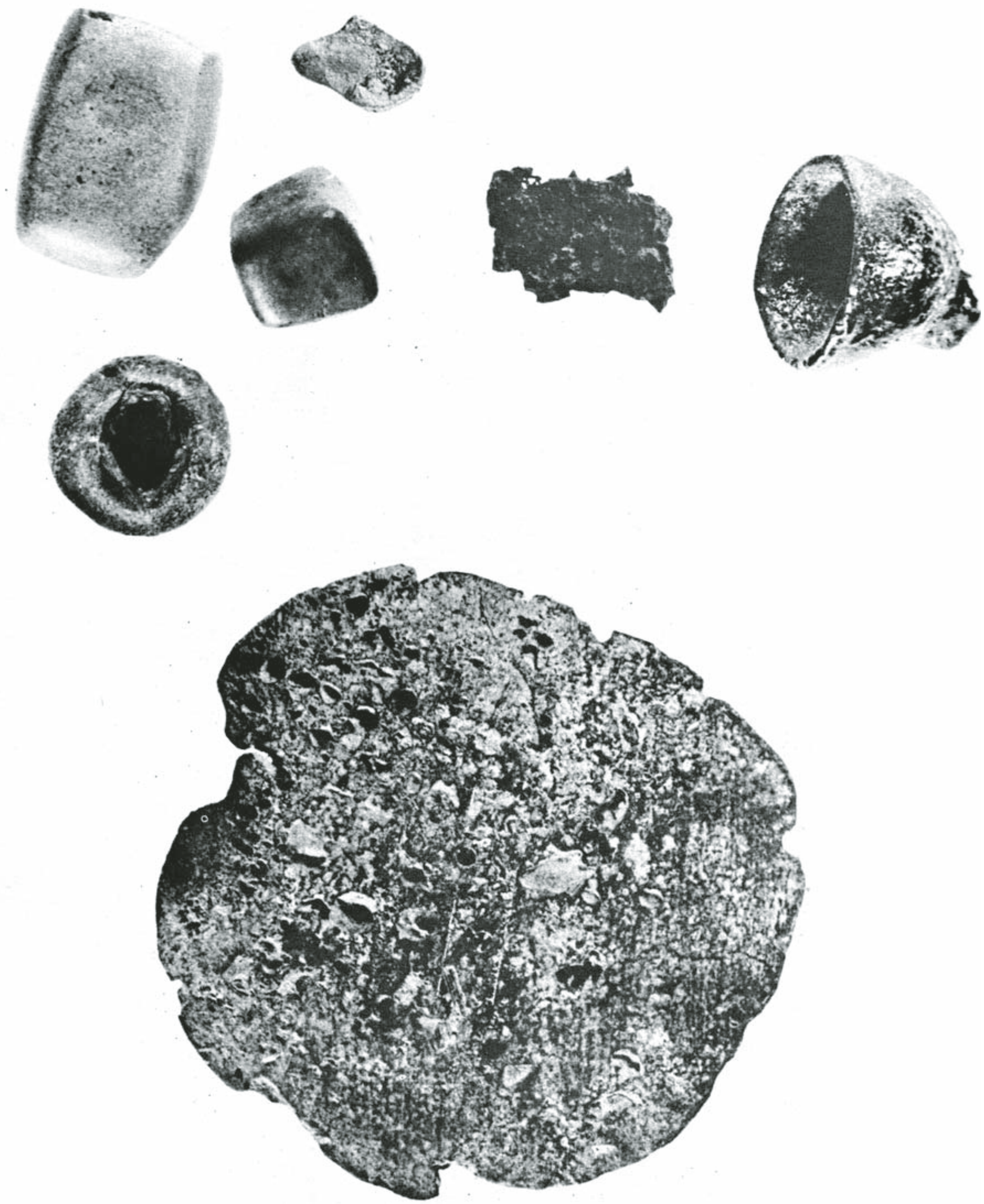

Figure 11. Tools for metalworking: two crucibles for smelting, a fragment of smelter scoria, a copper ingot obtained by smelting copper sulfides, two polished hammers (no handle) and a partially worked copper ingot. (The American Museum of Natural History, New York.)

Figure 12. Woodcut showing pre-Columbian metalworkers smelting and working gold and silver. (G. Benzoni, 1572, Libro III, p. 170.)

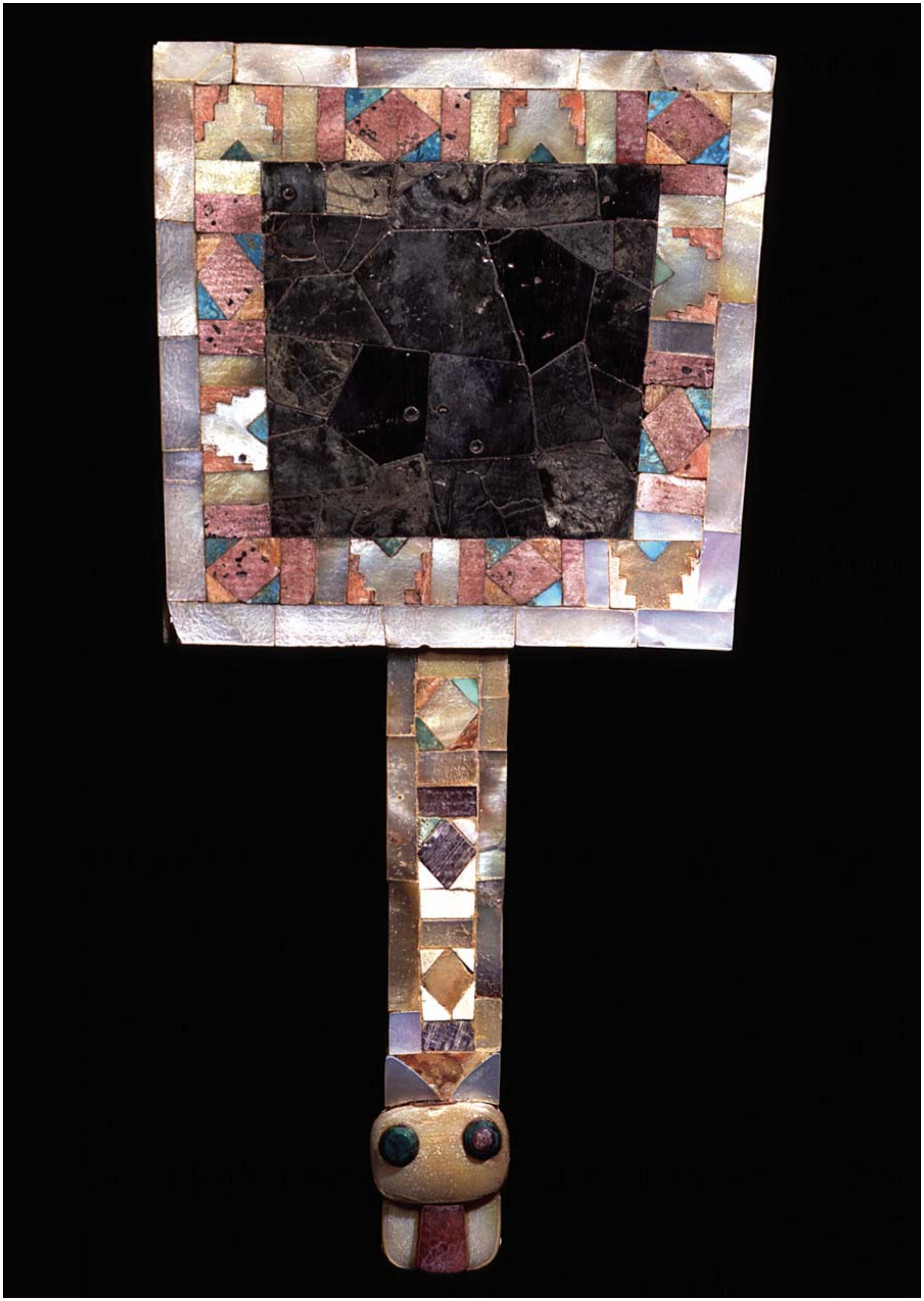

Figure 13 (*on this and following page*). Mirror made of a mosaic of pyrite, turquoise, and shell, from the central or southern coastal area of Perú, Coastal Tiahuanaco style. From the Robert Woods Bliss Collection, Pre-Columbian Art, Catalog no. 310, plates CXXVI and CXXVII, Ed. Phaidon Press, London; Dumbarton Oaks, Washington, D.C., PC.B. 432.

Figure 13 (*continued*).

APPENDIX: SELECTED BIBLIOGRAPHY

Plate tectonics became well-known in the late 1960s and provided a global framework for understanding many types of mineral deposits, distribution of volcanoes, and earthquakes. Many of Perú's occurrences of gold, silver, copper, and mercury are the result of regional tectonism and volcanism related to subduction of the Nazca plate beneath the South American plate. Gold, silver, and copper were the primary metals used in ancient Perú, and today, Perú is the world's leading producer of silver, the world's second leading producer of copper, and the leading producer of gold in Latin America. Mercury was also produced and used in ancient Perú and other parts of Latin America for small-scale gold mining, silver processing, and its use continues today for small-scale gold mining in Madre de Dios, Piura, La Libertad, Puno, and many other locations in Perú.

The effects of subduction have resulted in geologic hazards that include earthquakes, debris flows or *huaycos*, volcanic eruptions, tsunamis, and glacial releases. In 1970, tens of thousands were killed by an earthquake-induced debris flow in northern Perú. Ancient Perú was also affected by these hazards and Pachacamac or "the one who moves the earth" was the name of the ancient god who was responsible for seismicity as well as the name of an archaeological site near Lima. Earthquake-induced tsunamis have caused flooding and loss of life in the coastal areas of northern and southern Perú. Intense rain and flooding from episodic El Niño events threaten many of the adobe-walled archaeological sites in northern Perú.

The presence of coal implies a warmer climate in the geologic past and Perú's coal, even though highly tectonized and locally referred to as *cisco*, was used for jewelry, mirrors, and fuel. Guano found on many offshore islands is the result of the interaction of climate, seasonally changing ocean currents, as well as the feeding and resting habits of the sea birds. Ancient artifacts have been found in the guano, and reed boats, or *caballitos de totora*, were used to reach the offshore islands and transport the guano to the mainland. The nitrogen- and phosphate-rich guano was an important fertilizer that was used to produce the cotton that was used for ancient Peruvian textiles. In the mid-1800s, Peruvian guano was an important commodity and exports to Britain exceeded US$20 billion. The *caballitos* are still common on the beaches near Trujillo, northern Perú.

Since publication of Petersen's *Mining and Metallurgy in Ancient Perú* in 1970, a great number of journal articles and books have been published that use and expand on Petersen's chemical analyses of metallic artifacts, extensive mining and metallurgical observations, geoarchaeology, rock and tool descriptions, and research on the use and importance of metals and mineral resources in ancient Perú. I have tried to compile some of those references, as well as some earlier research, in the following bibliography. I wish to express my gratitude to colleagues and reviewers for their suggested additions and sincerely apologize for any omissions.

William E. Brooks

Cremation and the Chan Chan Burned Site

Brooks, W.E., 2004, Coal and cremation at Chan Chan northern Peru, geochemical evidence: Geological Society of America Abstracts with Programs, v. 36, no. 2, p. 65.

Brooks, W.E., Galvez Mora, C., Jackson, J.C., McGeehin, J.P., and Hood, D.G., 2008, Coal and cremation at the Tschudi burn, Chan Chan, northern Peru: Archaeometry, v. 50, no. 3, p. 495–515.

Duncan, W.N., Balkansky, A.K., Crawford, K., Lapham, H.A., and Meissner, N.J., 2008, Human cremation in Mexico 3000 years ago: Proceedings of the National Academy of Sciences of the United States of America, v. 105, no. 14, p. 5315–5320.

Lechtman, H.N., and Moseley, M., 1975, The scoria at Chan-Chan, non-metallurgical deposits: Nawpa Pacha, v. 10, no. 12, p. 135–185.

The Chuquicamata Mummy

Bird, J.B., 1979, The copper man, a prehistoric miner and his tools from northern Chile, *in* Benson, E.P., ed., Pre-Columbian Metallurgy of South America: Washington, D.C., Dumbarton Oaks Research Library and Collections, p. 105–131.

Fuller, D.R., 2004, The production of copper in 6th century Chile's Chuquicamata mine: Journal of Metals, v. 56, no. 11, p. 62–66.

Cinnabar, Mercury, and Small-Scale Gold Mining

Arana, P.P., 1901, Las minas de azogue del Perú: Imprenta El Lucero, no. 321, Lima, 103 p.

Brooks, W.E., 2010, Industrial use of mercury in the ancient world, *in* Bank, M., ed., Mercury in the Environment—Pattern and Process: School of Public Health, Harvard University (in press).

Brooks, W.E., Sandoval, E., Yepez, M., and Howard, H., 2007, Peru mercury inventory 2006: U.S. Geological Survey Open-File Rept. 2007-1252, http://pubs.usgs.gov/of/2007/1252/.

Brooks, W.E., Schwörbel, G., and Castillo, L.E., 2009, Mercury and small-scale gold mining in ancient Peru: Geological Society of America Annual Meeting, Abstracts with Programs, v. 41, no. 7, p. 435.

Brooks, W.E., Schwörbel, G., and Castillo, L.E., 2010, Amalgamation and small-scale gold mining in the ancient Andes (unpublished manuscript).

Brown, K.W., 2001, Worker's health and colonial mercury mining at Huancavelica, Peru: The Americas: The Academy of American Franciscan History, v. 57, no. 4, p. 467–496.

Burger, R., and Matos, R., 2002, Atalla, a center on the periphery of the Chavin horizon: Latin American Antiquity, v. 13, no. 2, p. 10–25.

Cánepa, C., ed., 2005, Minería a pequeña escala en la costa sur media del Peru: Dirección de Geología Económica y Prospección Minera, Boletin 3, Serie E: Mineria, Instituto Geologico Minero y Metalurgico, 79 p.

Cooke, C.A., Balcom, P.H., Biestar, H., and Wolfe, A.P., 2009, Over three millennia of mercury pollution in the Peruvian Andes: Proceedings of the National Academy of Sciences, http://www.pnas.org/cgi/doi/10.1073/pnas.0900517106.

Crozier, R.D., 1993, Silver processing in Spanish America, the patio and buytron processes: Canadian Mining and Metallurgical Bulletin, v. 86, no. 972, p. 86–91.

Gold Slaves, a video documentary on small-scale gold mining at 5000 m under glacial ice at La Rinconada, Perú (see Petersen, 1970, figure 3), http://www.youtube.com/watch?v=DYkHZdSiTqE.

Larco Hoyle, R., 2001, La metalurgia y la orfebrería, *en* Los Mochicas, tomo II, Lima, Museo Arqueológico Rafael Larco Herrera, p. 128–139.

Larmer, R., 2009, The price of gold: National Geographic, v. 215, no. 1, p. 34–61.

Lozano, Hernando, 1987, Minerales de mercurio, *in* Villegas Betancourt, Alberto, ed., Recursos Minerales de Colombia, Tomo I, Metales: Publicaciones Geologicas Especiales del INGEOMINAS, Bogota, no. 17, p. 275–291.

McKee, E.H., Noble, D.C., and Vidal, Cesar, 1986, Timing of volcanic and hydrothermal activity, Huancavelica mercury district, Peru: Economic Geology and the Bulletin of the Society of Economic Geologists, v. 81, no. 2, p. 489–492.

Olivari Ortega, J., 2006, Las acequias Incas para obtener oro: Historia Minera, El Ingeniero de Minas, v. 41, Colegio de Ingenieros del Perú, May-June, p. 26–27.

Pendergast, D.M., 1982, Ancient Maya mercury: Science, v. 217, no. 6, p. 533–535.

Truhan, D.L., Burton, J.H., and Bruhns, K.O., 2005, El cinabrio en el mundo Andino: Revista de Antropología 18, La Casa de La Cultura Ecuatoriana Benjamin Carrion, Cuenca, Ecuador, p. 193–205.

Yates, R.G., Kent, D.F., and Fernandez, J., 1951, Geology of the Huancavelica quicksilver district, U.S. Geological Survey Bulletin 975-A, p. 1–45.

Coal

Agramonte, J., and Diaz, A., 1983, Inventario preliminar del carbon mineral en el Perú: Instituto Geológico, Minero y Metalúrgico, Lima.

Alvarado, B., 1980, Recursos de carbon in Suramerica: Revue de l'Institut Français du Pétrole, v. 35, no. 2, p. 387–421.

Brooks, W.E., and Willett, J.C., 2004, Update, World Coal Quality Inventory—Peru: U.S. Geological Survey Open-File Report 2004-1023, http://pubs.usgs.gov/of/2004/1023/index.html.

Brooks, W.E., Finkelman, R.B., Willett, J.C., Gurmendi, A.C., and Yager, T.R., Carrascal, Rolando, and Mucho, Romulo, 2006, World Coal Quality

Inventory—Peru: Chapter 6 of World Coal Quality Inventory, South America: U.S. Geological Survey Open-File Report 2006-1241, http://pubs.usgs.gov/of/2006/1241/index.html.

Carrascal, R., Matos, C., and Silva, O., 2000, Carbon en el Perú: Instituto Geológico, Minero y Metalúrgico, Boletin 7, Lima, 150 p.

Dunin-Borkowski, E., 1989, Caracteristicas geológicas, distribución geografica y aprovechamiento de los carbones Peruanos: Carbon Energetico Electrico Siderugico Industrial-El Primer Simposio, Lima, Empresa Siderugica del Perú, p. 6–7.

Dunin-Borkowski, E., 1996, Minerales industriales del Perú: Lima, Perú, Publicacion Especial, Instituto Geológico Minero y Metalúrgico, 166 p.

Escudero, J., 1978, El carbon del Alto Chicama: Instituto Geológico, Minero y Metalúrgico, Boletin 2, Lima, 45 p.

Petersen, C.R., 1983, Coal resources of Perú, *in* Kottlowski, F.E., Cress, A.T., and Meyerhoff, A.A., eds., Coal Resources of the Americas, Selected Papers: Geological Society of America Special Paper 179, p. 35–42.

General

Agricola, G., 1556/1912, De Re Metallica: London, 638 p., translated by H.C. Hoover and L.H. Hoover and reprinted in 2005 from the 1912 edition, New York, Kessinger Publishing, 638 p.

Brooks, W.E., Kent, J.D., and Willett, J.C., 2004, Mineral, energy, and fertilizer resources of the north coast of Perú: U.S. Geology Survey Open-File Report 2004-1024, http://pubs.usgs.gov/of/2004/1024.

Burger, R.L., 2004, Scientific insights into daily life at Machu Picchu, *in* Burger, R.L., and Salazar, L.C., eds., Machu Picchu, unveiling the mystery of the Incas: New Haven, Yale University Press, p. 85–106.

Cathro, R.J., 2000, The history of mining and metallurgy in Latin America, 1500 BC–1600 AD, *in* Sherlock, R., and Logan, A., eds., Volcanogenic Massive Sulfide Deposits of Latin America, Geological Association of Canada, Mineral Deposits Division, Special Publication 2, p. 1–17.

Craddock, P.T., 1995, Early metal mining and production: Washington, D.C., Smithsonian Institution, 245 p.

Craig, J.R., Vaughan, D.J., and Skinner, B.J., 2001, Resources of the Earth, origin, use and environmental impact: Upper Saddle River, New Jersey, Prentice-Hall, 520 p.

Dunin-Borkowski, E., 1996, Minerales industriales del Perú: Lima, Perú, Publicacion Especial, Instituto Geológico Minero y Metalúrgico, 166 p.

Herz, N., and Garrison, E.G., 1998, Geological methods for archaeology: Oxford Press, New York.

Kauffman Doig, F., 1978, Manual de arqueologia Peruana: Lima, Empresa Editorial, 800 p.

Noble, D.C., and Vidal, C.E., 1994, Gold in Perú: Society of Economic Geologists Newsletter, v. 17, p. 1–13.

Petersen, U., Vidal, C.E., and Noble, D.C., 1990, A special issue devoted to the mineral deposits of Perú: Economic Geology, v. 85, no. 7, 289 p.

Porras Barrenechea, R., and Mujica Gallo, M., 1959, Gold museum gold of Perú: Recklinghausen, Germany, Aurel Bongers, 305 p.

Rapp, G., 2002, Archaeomineralogy: Springer, New York, 326 p.

Salazar, L.C., 2004, Catalog, stone objects, *in* Burger, R.L., and Salazar, L.C., eds., Machu Picchu, unveiling the mystery of the Incas: New Haven, Yale University Press, p. 157–204.

Samamé Boggio, M., 1979, El Perú minero: Instituto Cientifico y Tecnológico Minero, Lima.

Schreiber, D.A., Fontbote, L., and Lochmann, D., 1990, Geologic setting, paragenesis, and physicochemistry of gold quartz veins hosted by plutonic rocks in the Pataz region: Economic Geology and the Bulletin of the Society of Economic Geologists, v. 85, no. 2, p. 1328–1347.

Scott, D.A., and Meyers, Pieter, eds., 1994, Archaeometry of pre-Columbian sites and artifacts: University of California at Los Angeles Institute of Archaeology and the Getty Conservation Institute, Los Angeles, California, 23–27 March 1992, p. 267–284.

Gold and Platinum

Aldenderfer, M., Craig, N.M., Speakman, R.J., and Popelka-Filcoff, Rachal, 2008, Four thousand year old gold artifacts from the Lake Titicaca basin, southern Peru: Proceedings of the National Academy of Sciences, v. 105, v. 13, p. 5002–5005.

Bray, W., 1988, Resolving the platinum paradox: Americas, v. 40, p. 45–49.

Meyer, A., 1941, In the Choco, Colombia: Engineering and Mining Journal, v. 142, no. 9, p. 35–39.

Restrepo, V., 1884, A study of the gold and silver mines of Colombia [translation by C.W. Fischer]: C. Jourgensen, New York, 320 p.

Scott, D.A., and Bray, W., 1980, Ancient platinum technology in South America: Platinum Metals Review, v. 24, no. 4, p. 147–157.

West, R.C., 1952, Colonial placer mining in Colombia: Louisiana State University, Baton Rouge, 157 p.

Guano/Fertilizer

Caldas, J., Palacios, O., Pecho, V., and Vela, C., 1980, Geología de los cuadrangulos de Bayovar, Sechura y Morrope: Instituto Geológico Minero y Metalúrgico Boletin, no. 32, Lima, Perú, 125 p.

Elton, C., 2001, Vaivenes de una industria milenaria: Ameríca̎s, v. 4, p. 6–15.

Julien, C.J., 1995, Guano and resource control in sixteenth century Arequipa, *in* Masuda, S., Shimada, I., and Morris, C., eds., Andean Ecology and Civilization, University of Tokyo, Tokyo, p. 185–231.

Rostworowski de Diez Canseco, M., 1997, The coastal islands of Peru, *in* Berrin, K., ed., The Spirit of Ancient Peru: New York, Thames and Hudson, 216 p.

Stillwell, A.G., 1942, Fertilizers, ch. 13, *in* Furnas, C.C., ed., Rogers Industrial Chemistry, Van Nostrand, New York, p. 501–509.

Hazards

Arnao, B.M., 1998, Glaciers of Perú, *in* Williams, R.S., and Ferrigno, J.G., eds., Glaciers of South America, U.S. Geological Survey Professional Paper 1386-I, 25 p.

Brooks, W.E., Willett, J.C., Kent, J.D., Vasquez, V., and Rosales, T., 2005, The Muralla Pircada, an ancient Andean debris flow retention dam, Santa Rita B archaeological site, Chao Valley, northern Peru: Landslides, v. 2, p. 117–123.

Burger, R.L., 2003, El Niño, early Peruvian civilization, and human agency, some thoughts from the Lurin Valley, *in* Haas, J., and Dillon, M.O., eds., El Niño in Perú, biology and culture over 10,000 years, Fieldiana Botany, Field Museum of Natural History, no. 43, publication 1524, p. 90–107.

Craig, A.K., and Shimada, I., 1986, El Niño flood deposits at Batan Grande, northern Perú: Geoarchaeology, v. 1, p. 29–38.

Doore, K., 1998, Pachacamac, solar temple and oracular destination of the ancient Americas (http://www.labyrinthina.com/pachacamac.htm).

Fidel Smool, L., Martinez Guzman, A., Zegarra Loo, J., Vilchez Mata, M., Colque Tula, J., and Jackson, L.E., 2005, Investigation of the origin and magnitude of debris flows from the Payhua Creek basin, Matacana area, Huarochiri Province, Peru, *in* Hungr, O., Fell, R., Couture, R., and Eberhardt, E., eds., Landslide Risk Management: Proceedings of the International Conference on Landslide Risk Management, p. 467–473.

Keefer, D.K., Moseley, M.E., and Satterlee, D.R., 1996, Recognizing seismic input in flood sediments, case study in the Ilo-Moquegua area, southern Perú: Geological Society of America Abstracts with Programs, v. 28, no. 7, p. A301.

Keefer, D.K., 1999, Earthquake-induced landslides and their effects on alluvial fans: Journal of Sedimentary Research, v. 69, no. 1, p. 84–104.

Keefer, D.K., Moseley, M.E., Satterlee, D.R., and DeFrance, S.D., 2000, El Niño generated floods dating from 38.2 Ka to 1998 at archaeological sites along the far south coast of Perú: Geological Society of America Abstracts with Programs, v. 32, no. 7, p. A262.

Moseley, M.E., 1987, Punctuated equilibrium, searching the ancient record for El Niño: Quarterly Review of Archaeology, fall, p. 7–10.

Moseley, M.E., and Richardson, J.B., 1992, Doomed by natural disaster: Archaeology, v. 45, no. 6, p. 44–45.

Ortlieb, L., and Vargas, G., 2003, Debris-flow deposits and El Niño impacts along the hyperarid southern Peru coast, *in* Haas, J., and Dillon, M.O., eds., El Niño in Perú, biology and culture over 10,000 years, Fieldiana Botany, Field Museum of Natural History, no. 43, publication 1524, p. 24–51.

Piminchumo, V., and Galvez, C., 2003, La muralla de la Cumbre: Revista Arqueologíca Sian, v. 8, no. 14, p. 18–25.

Plafker, G.G., and Ericksen, E.G., 1978, Nevados Huascarán avalanches, *in* Voight, B., ed., Rockslides and avalanches, natural phenomena: New York, Elsevier, p. 277–314.

Rollins, H.B., Richardson, J.B., and Sandweiss, D.H., 1986, The birth of El Niño, geoarchaeological evidence: Geoarchaeology, v. 1, no. 1, p. 3–15.

Stillwell, H.D., 1992, Natural hazards and disasters in Latin America: Natural Hazards, v. 6, no. 1, p. 131–159.

University of Southern California Tsunami Research Group, 1996, Historical tsunamis originating off the Peruvian coast: http://www.usc.edu/dept/tsunamis/peru/ptsu_hist.html.

Wells, L.E., 1990, Holocene history of the El Niño phenomenon as recorded in flood sediments of northern coastal Perú: Geology, v. 18, p. 1134–1137, doi:10.1130/0091-7613(1990)018<1134:HHOTEN>2.3.CO;2.

Tsunami Research Group, 2005, The 1996 Chimbote tsunami: University of Southern California Tsunami Research Group, http://www.usc.edu.

Minerals, Gems, and Pigments

Bonavia, D., 1985, Mural painting in ancient Peru: Bloomington, Indiana University Press, 224 p.

Brooks, W.E., Piminchumo, V., Suarez, H., Jackson, J.C., and McGeehin, J.P., 2006, Mineral pigments from Tacaynamo, Chan Chan, northern Peru: Geological Society of America Abstracts with Programs, v. 38, no. 7, p. 233.

Brooks, W.E., Piminchumo, V., Suarez, H., Jackson, J.C., and McGeehin, J.P., 2008, Mineral pigments from Huaca Tacaynamo, Chan Chan, northern Peru: Bulletin de Institute Francais d'Etudes Andines, Lima, v. 37, no. 3, p. 1–10.

Del Castillo, G., 2004, Joyas de la tierra, minerales del Perú: Didi de Arteta, S.A., Lima, 194 p.

Farnsworth, M.A., 1951, Ancient pigments: Journal of Chemical Education, v. 28, p. 72–76.

Jackson, M.A., 2004, The Chimu sculptures of Huacas Tacaynamo and El Dragón, Moche Valley, Peru: Latin: American Antiquity, v. 15, no. 3, p. 298–322.

Pillsbury, J., 1993, Sculpted friezes of the Empire of Chimor [Ph.D. dissertation]: New York, Columbia University, 450 p.

Schaedel, R.P., 1978, The Huaca Pintada of Illimo: Archaeology, v. 31, no. 1, p. 27–37.

Scott, D.A., Doughty, D.H., and Donnan, C.B., 1998, Moche wallpainting pigments from La Mina, Jequetepeque, Peru: Studies in Conservation, v. 43, p. 177–182.

Wainwright, I., and Raudsepp, M., 2008, Identificación de pigmentos de pinturas rupestres de Paja Colorada, Prov. Vallegrande, Depto. de Santa Cruz: Sociedad de Investigacion de Arte Rupestre de Bolivia, Noviembre, no. 22, p. 41–45.

Mining, Metallurgy, and Alloys

Abbott, M.A., and Wolfe, A.P., 2003, Intensive Pre-Incan metallurgy recorded by lake sediments from the Bolivian Andes: Science, v. 301, 26 September, p. 1893–1895.

Brooks, W.E., and Van Buren, M., 2007, Dirty galena at Porco, Bolivia: Geological Society of America Abstracts with Programs, v. 39, no. 6, p. 549.

Bruhns, K.O., 1970, A Quimbaya gold furnace: American Antiquity, v. 35, p. 202–203.

Burger, R.L., and Gordon, R.B., 1998, Early central Andean metalworking from Mina Perdida, Perú: Science, v. 282, p. 1108–1111.

Cooke, C.A., Abbott, M.A., Wolfe, A.P., and Kittleson, J.L., 2007, A millennium of metallurgy recorded by lake sediments from Morococha, Peruvian Andes: Environmental Science & Technology, v. 41, no. 10, p. 3469–3474.

Cooke, C.A., Balcom, P.H., Biestar, H., and Wolfe, A.P., 2009, Over three millennia of mercury pollution in the Peruvian Andes: Proceedings of the National Academy of Sciences, http://www.pnas.org/cgi/doi/10.1073/pnas.0900517106.

Donnan, C.B., 1973, A pre-Columbian smelter from northern Perú: Archaeology, v. 26, no. 4, p. 289–297.

Gemuts, I., Lopez, G., and Jiménez, F., 1992, Gold deposits of southern Ecuador: Society of Economic Geologists Newsletter, no. 11, p. 1–16.

Gonzalez, A.R., 1979, Pre-Columbian metallurgy of northwest Argentina, historical development and cultural process, *in* Benson, E.P., ed., Pre-Columbian Metallurgy of South America: Washington, D.C., Dumbarton Oaks Research Library and Collections, p. 133–202.

Gordon, R.B., and Rutledge, J.W., 1984, Bismuth bronze from Machu-Picchu, Peru: Science, v. 223, no. 4636, p. 585–586.

Gordon, R.B., and Knopf, R., 2006, Late horizon silver, copper, and tin from Machu Picchu, Peru: Journal of Archaeological Science, v. 34, no. 1, p. 38–47.

Gordon, R.B., and Knopf, R., 2006, Metallurgy of bronze used in tools from Machu Picchu, Peru: Archaeometry, v. 48, no. 1, p. 57–76.

Grossman, J.W., 1972, An ancient gold worker's tool kit: Archaeology, v. 25, no. 4, p. 270–275.

Holloway, H.L., 1932, Gold in Ecuador: Mining Magazine (London), v. 46, p. 219–223.

Horz, G., and Kallfass, M., 1998, Pre-Columbian metalworking in Perú—Ornamental and ceremonial objects from the royal tombs of Sipan: Journal of Metallurgy, v. 50, no. 12, p. 8–16.

Lindgren, Waldemar, and Creveling, J.G., 1928, The ores of Potosi, Bolivia: Economic Geology and the Bulletin of the Society of Economic Geologists, v. 23, no. 3, p. 233–262.

Lleras Perez, R., ed., 2007, Metalurgía en la Amérίca Antígua: Instituto Francés de Estudios Andinos, Lima, 600 p.

Peele, R., 1893, A primitive smelting furnace: Columbia College School of Mines Quarterly, v. 15, p. 8–10.

Lechtman, H., 1976, A metallurgical site survey in the Peruvian Andes: Journal of Field Archaeology, v. 3, no. 1, p. 1–42.

Lechtman, H., 1979, Issues in Andean metallurgy, *in* Benson, E.P., ed., Pre-Columbian Metallurgy of South America: Washington, D.C., Dumbarton Oaks Research Library and Collections, p. 1–40.

Lechtman, H., 1980, The central Andes, metallurgy without iron, *in* Wertime, T.A., and Muhly, J.D., eds., The Coming of the Age of Iron: New Haven, Yale University Press, p. 267–334.

Lechtman, H., 1988, Traditions and styles in central Andean metalworking, *in* Maddin, R., ed., The Beginning of the use of metals and alloys: Boston, Massachusetts Institute of Technology Press, p. 344–378.

Lechtman, J., Erlij, A., and Barry, E.J., 1982, New perspectives on Moche metallurgy, techniques of gilding copper at Loma Negra, northern Perú: American Antiquity, v. 47, no. 1, p. 3–30.

Pfordte, O.F., 1893, Ancient method of silver-lead smelting in Perú: Transactions of the American Institute of Mining Engineers, v. 21, p. 25–30.

Rutledge, J.W., and Gordon, R.B., 1987, The work of metallurgical artificers at Machu Picchu, Peru: American Antiquity, v. 53, no. 3, p. 578–594.

Shimada, I., 1994, Pre-Hispanic metallurgy and mining in the Andes, recent advances and future tasks, *in* Craig, A.K., and West, R.C., eds., In Quest of Mineral Wealth, Aboriginal and Colonial Mining and Metallurgy in Spanish America, Geoscience and Man: Baton Rouge, Louisiana, Louisiana State University, Department of Geography and Anthropology, v. 33, p. 37–73.

Shimada, I., Epstein, S., and Craig, A.K., 1983, The metallurgical process in ancient northern Peru: Archaeology, v. 35, no. 5, p. 38–45.

Shimada, I., and Griffin, J.A., 2005, Precious metal objects of the Middle Sican: Scientific American, v. 15, no. 1, p. 80–89.

Shimada, I., and Merkel, J.F., 1991, Copper-alloy metallurgy in ancient Perú: Scientific American, v. 265, no. 1, p. 80–86.

Van Buren, M., and Mills, B.H., 2005, Huayrachinas and tocochimbos, traditional smelting technology of the southern Andes: Latin: American Antiquity, v. 16, no. 1, p. 3–25.

Vaughan, K.J., Linares, M., Eerkens, J.W., and Edwards, M.J., 2007, Hematite mining in the ancient Americas, Mina Primavera, a 2000 year old Peruvian mine: Journal of Metals, December, v. 115, no. 4, p. 16–20.

Ornamental and Industrial Stone

Protzen, J.P., 1986, Inca stonemasonry: Scientific American, v. 254, no. 2, p. 94–105.

Petroleum

Stothert, K.E., 1994, Early petroleum extraction and tar-boiling in coastal Ecuador, *in* Craig, A.K., and West, R.C., eds., In Quest of Mineral Wealth, Aboriginal and Colonial Mining and Metallurgy in Spanish America: Baton Rouge, Louisiana, Louisiana State University, Department of Geography and Anthropology, p. 343–354.

Salt

Peele, R., 1893, A Peruvian salt mine: Columbia College School of Mines Quarterly, v. 15, p. 219–221.

Terminology

Long, K.R., 1991, A glossary of Spanish geological and mining terms: U.S. Geological Survey Open-File Report, 91-579, 155 p.

Manuscript Accepted by the Society 20 April 2009

Printed in the USA