SWEAT OF THE SUN, TEARS OF THE MOON

Gold funerary mask from La Tolita, Ecuador.

With almond shaped eyes and recessed pupils. Probably dates from about 200 A.D.
Museo Casa de la Cultura, Guayaquil, Ecuador

Metals in Pre-Columbian Latin America

- Metals were highly appreciated by Pre-Columbian cultures. Gold and silver were considered of divine origin.
- Color, shine and sound were main reasons to prefer this materials for ornaments and sacred artifacts.
- Copper and bronze were later used to produce tools and weapons but never replaced the use of stone and obsidian.

Stages in the evolution of Pre-Iron Metallurgy

Four stages are recognized, Patterson 1971.

I. Native Metals were hammered and annealed. Gold, copper and silver were the first metals used because they were obtained in native state.

II. Reduction, smelting, melting and casting was achieved using oxide ores.

III. Use of alloys such as bronze

IV. Smelting of sulfide ores

Iron and steel production was never achieved in pre-Columbian LA

Times of Metallurgical development in the world

Euro Asiatic:

7800 B.C. TO 1200 B.C.

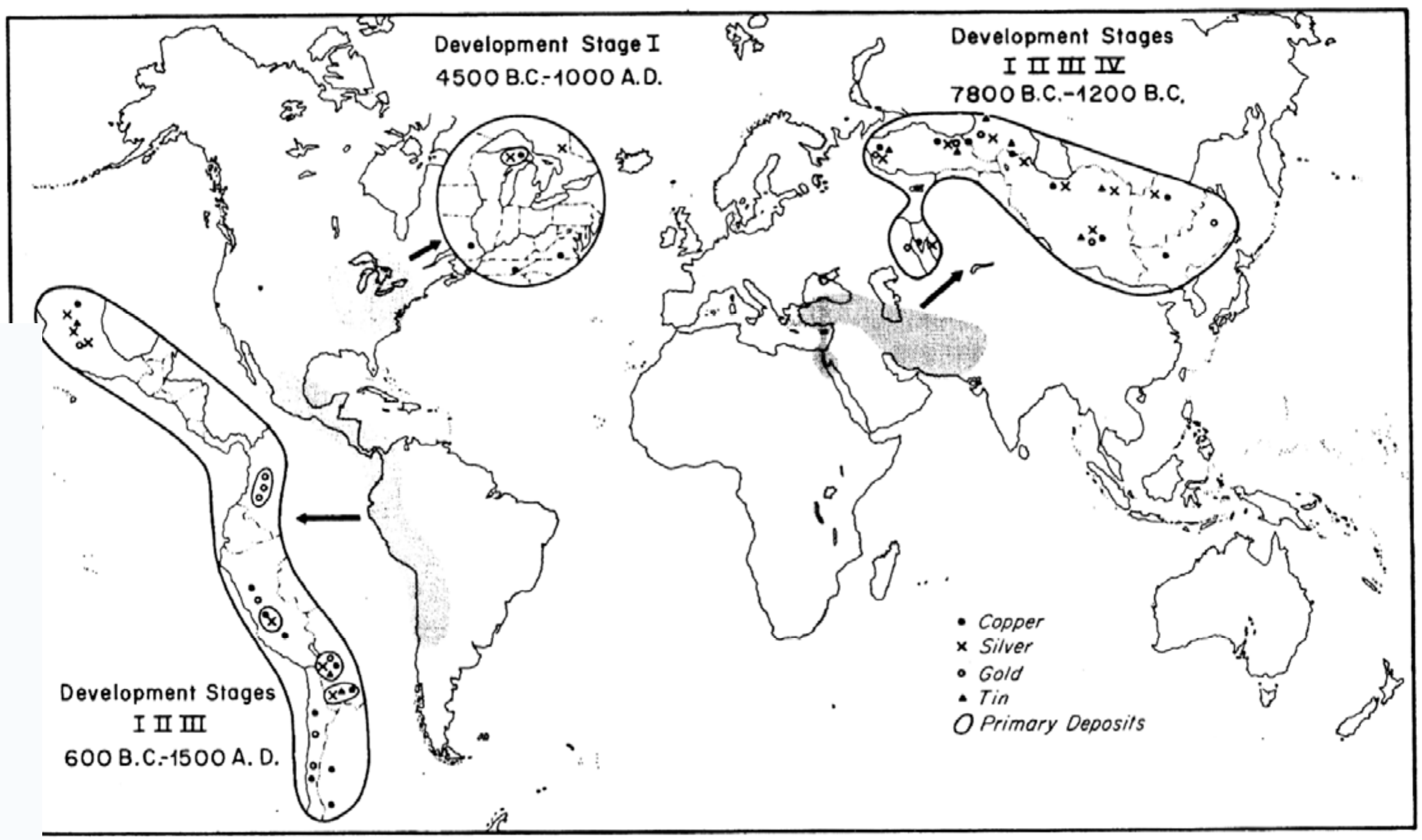
Stages 1,2,3, and 4

Great Lakes: 4500 B.C. to 1000 A.D.

Stage 1

Latin America: 600 B.C. to 1500 A.D.

Stages 1,2,3, and 4?

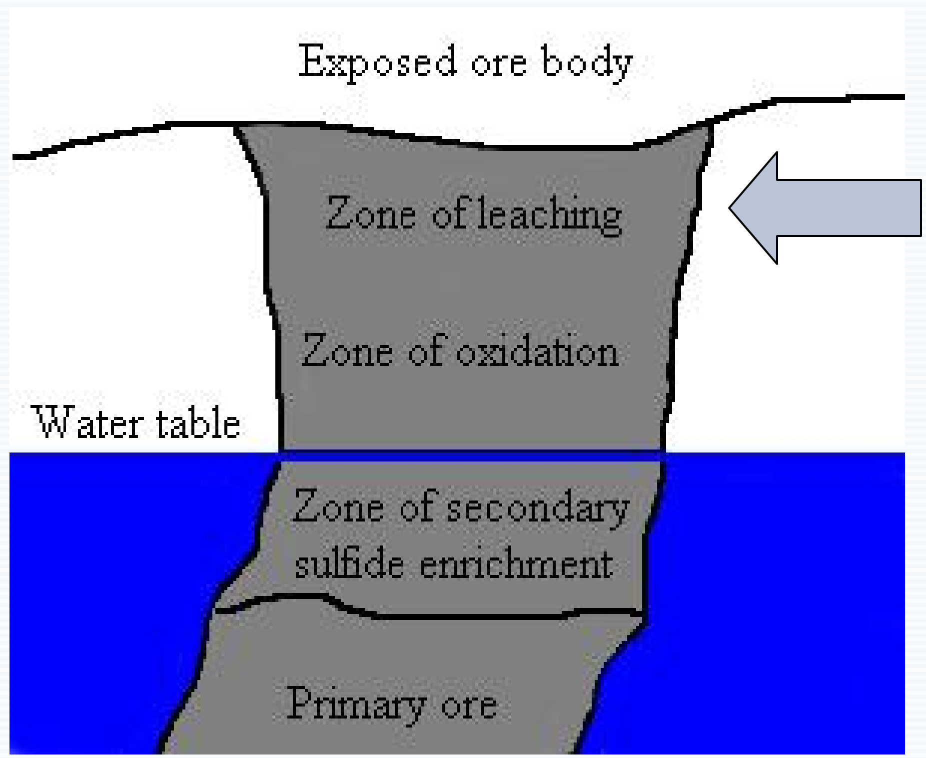


The three areas of independent formative metallurgical development and their likely sources of ore. From: Bateman (1950), Emmons (1937), Forbes (1964), Jones (1925), Miller and Singewald (1919), Tylecoat (1970), Weed (1907), Wertime (1964, 1968).

Geology and the use of ores, Stage 1

The use of minerals depends on the availability and the technology.

- Native metals were the first used, concentrated at surface in the zone of leaching.
- Placer concentration by erosive processes. The metal is pure enough to be used but not very abundant.

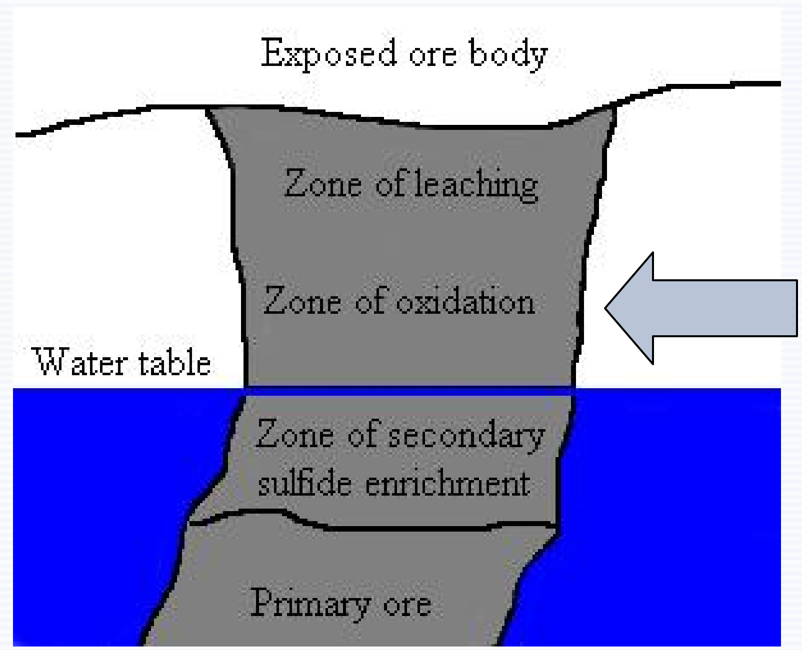


Geology and the use of ores, Stage 2

- Oxides and Carbonates: concentrated in the Oxidation Zone, sometimes exposed or mined without much difficulty. Smelting is a simple reduction process

Cuprite + Carbon monoxide= copper +CO_2

$CuO + CO = Cu + CO_2$



Stage 3, use of alloys: Bronze

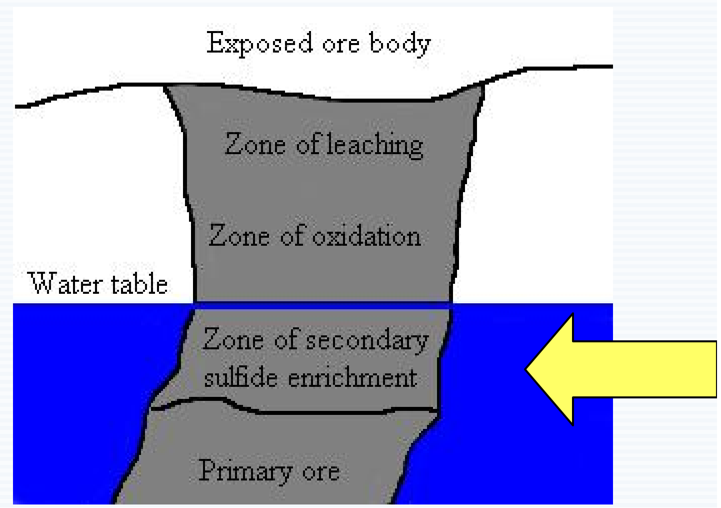
- Alloy: a substance that is a mixture of two or more metals, or of a metal with a nonmetallic material
- Bronze: is an alloy of copper, tin, arsenic, phosphorus, and small amounts of other elements.
- Bronzes are harder than brasses (copper and zinc).
- Most bronzes are produced by melting the copper and adding the desired amounts of arsenic, tin, phosphorous and other substances.
- Most of Pre-Columbian cultures were in the Bronze Age at the time of conquest. It is worth note that the use of metals was not widespread and stone artifacts and weapons were used extensively.

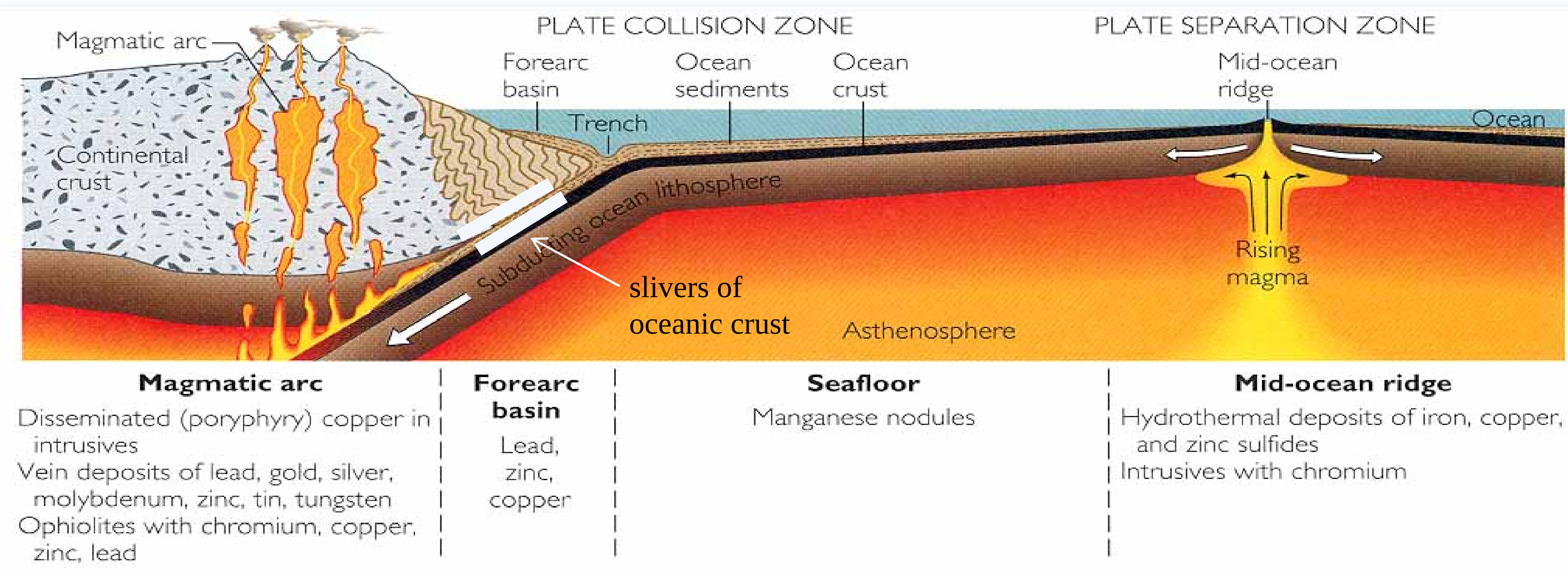
Geology and the use of ores Stage 4

- Sulfides formula: $Metal_X S_X$
- Sulfides: The zone below the water table is the sulfide zone.
- Sulfide zone deposits have a high metal content but are harder to mine: deeper and below the water table. It requires pumping or draining the water, and proper ventilation.

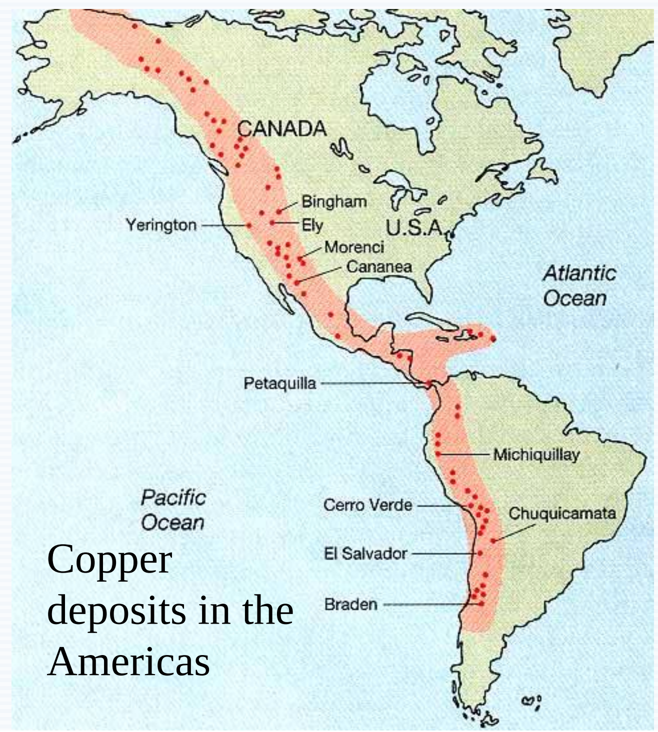
- Smelting of sulfide ores involves two stages:

1. Roasting: elimination of sulfur by oxidation
   $2CuS + 2O_2 = 2SO2 + 2CuO$
2. Reduction by carbon monoxide
   $CuO + CO = Cu + CO_2$



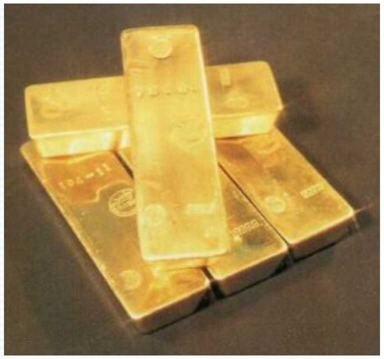


- Plate tectonics as a very useful model
  - Magmas related to subduction zone form the mineralization.



Copper deposits in the Americas

Gold



- Metallic chemical element, one of the transition elements, chemical symbol Au.
- In jewelry, its purity is expressed in 24ths, or karats: 24-karat is pure, 12-karat is 50% gold, etc.
- 24 K Pure; melting point: 1945ºF, 1063 ºC; Specific Gravity 19.32 (measure of weight per volume compared to water)
- Gold is widely distributed in all igneous rocks, usually pure but in low concentrations; its recovery from ores and deposits has been a major preoccupation since ancient times .
- The world's gold supply has seen three great leaps, with Christopher Columbus's arrival in the Americas in 1492, with discoveries in California and Australia (1850-75), and discoveries in Alaska, Yukon and South Africa (1890-1915).
- Pure gold is too soft for prolonged handling; it is usually used in alloys with silver, copper, and other metals.

PROPERTIES OF GOLD

This indestructible metal is completely recyclable and virtually immune to the effects of air, water, and oxygen. These properties include:

RESISTANCE TO CORROSION

Gold is the most non-reactive of all metals. It is benign in all natural and industrial environments. Gold never reacts with oxygen (one of the most active elements), which means it will not rust or tarnish.

DUCTILITY AND MALLEABILITY

Gold is the most ductile of all metals, allowing it to be drawn out into tiny wires or threads without breaking.

http://www.goldinstitute.org

Platinum

- Metallic chemical element, chemical symbol Pt, atomic number 78.
- A very heavy (specific gravity 21.4), silvery -white precious metal, it is soft and ductile, with a high melting point (3,216°F, or 1,769°C) and good resistance to corrosion and chemical attack.
- Platinum is usually found as alloys of 80-90% purity in placer deposits, or more rarely combined with arsenic or sulfur.

Placer deposits= river deposits

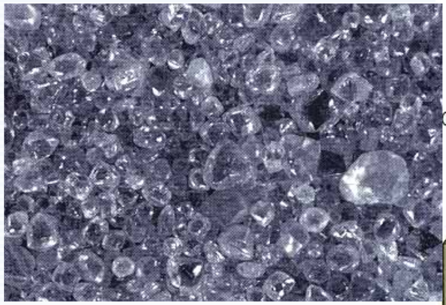
Sedimentary Concentration Mechanisms:

Sedimentary processes involve transport and deposition:

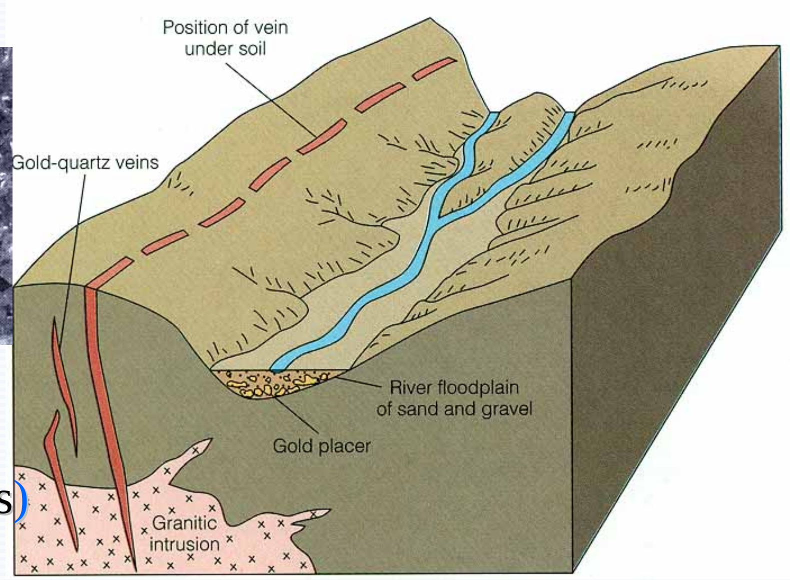
– Sand and gravel from old river channels, glacial deposits, deltas.

– Placer deposits concentrated weathering-resistant and heavy minerals (gold, silver, diamond, garnet etc.)

Gold nugget, California (2 cm)

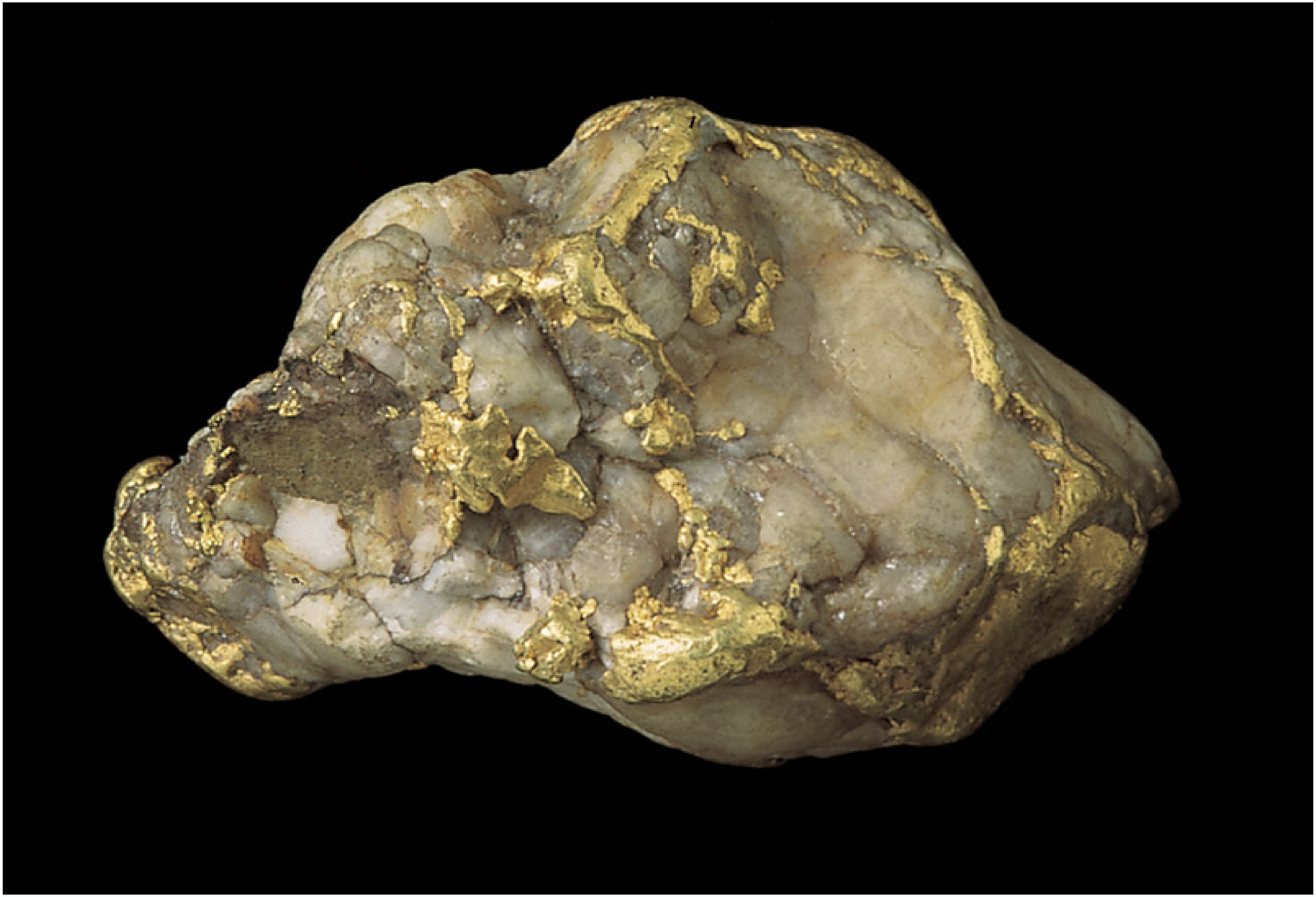


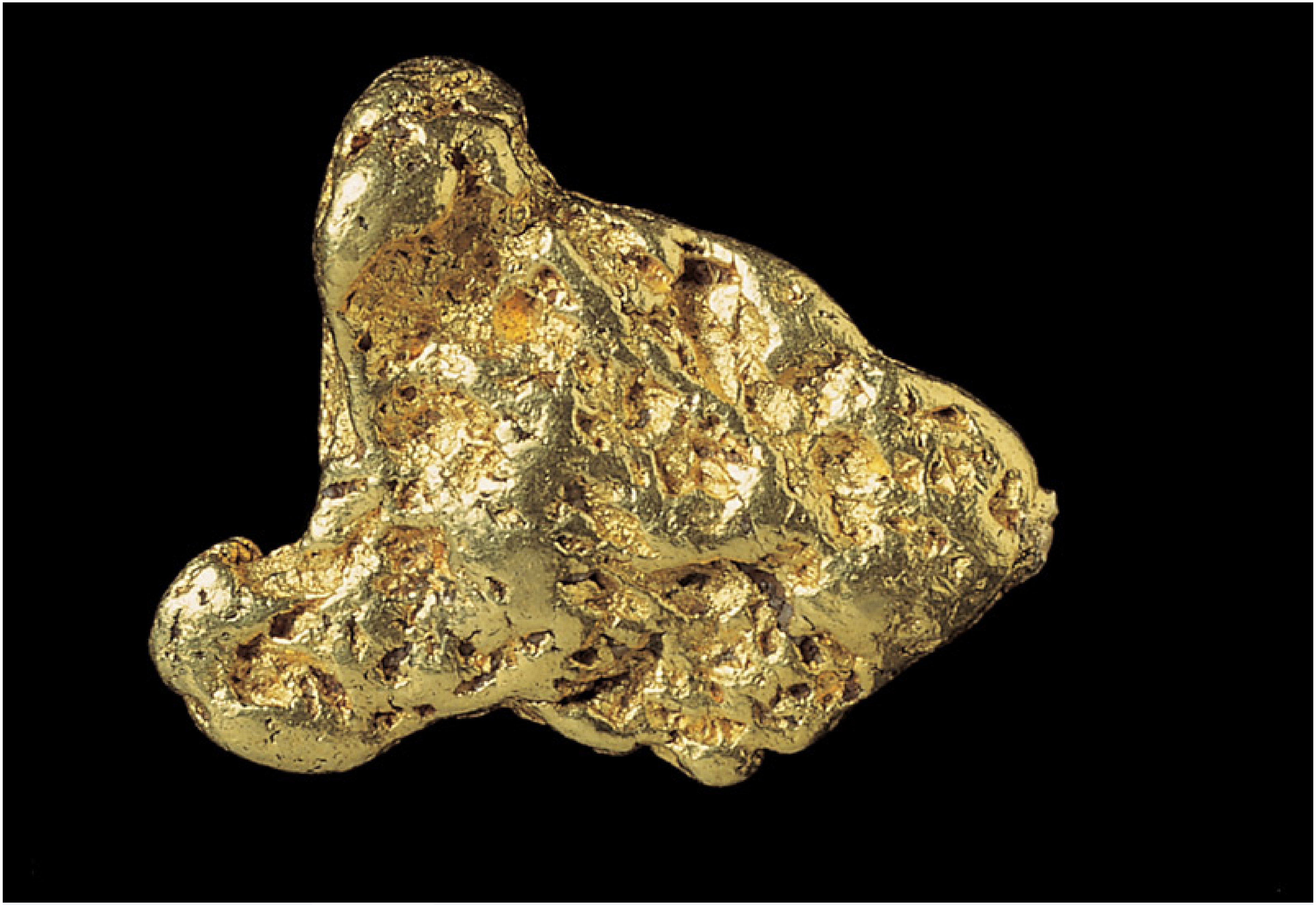
Placer diamonds, Namibia (3 cm across)



Placer Deposits

- Most placer gold occurs as grains the size of silt particles, the "gold-dust" of miners.
- Sometimes, the gold placer is larger and is called a nugget.
- Many heavy, durable minerals other than gold also form placers (platinum, copper, tinstone, diamond, ruby, and sapphire).





Pre-Columbian Mining Technologies

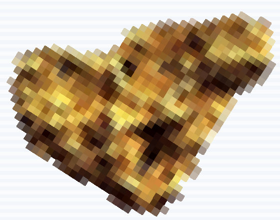
- Placer Mining
- Hard Rock Mining

Placer Mining in Pre-Columbian times

- Panning: early records indicate that gold and platinum were obtained by this process.

- Riffles – stone or wood structures constructed across a stream, collecting the nuggets and grains carried by the water.

AN INDIAN WOMAN PANNING OUT GOLD.



Hard Rock Mining in Pre-Columbian times

Extraction of native metals from veins in hard igneous rocks: silver, gold, copper.

- Silver mines in Mexico: Pachuca, Hidalgo, Tepic, Taxco.
- Andes native metal mines at Porca (silver), and La Paz (gold).

Actual artisan mining in Bolivia

Mining in Pre-Columbian times: ore extraction

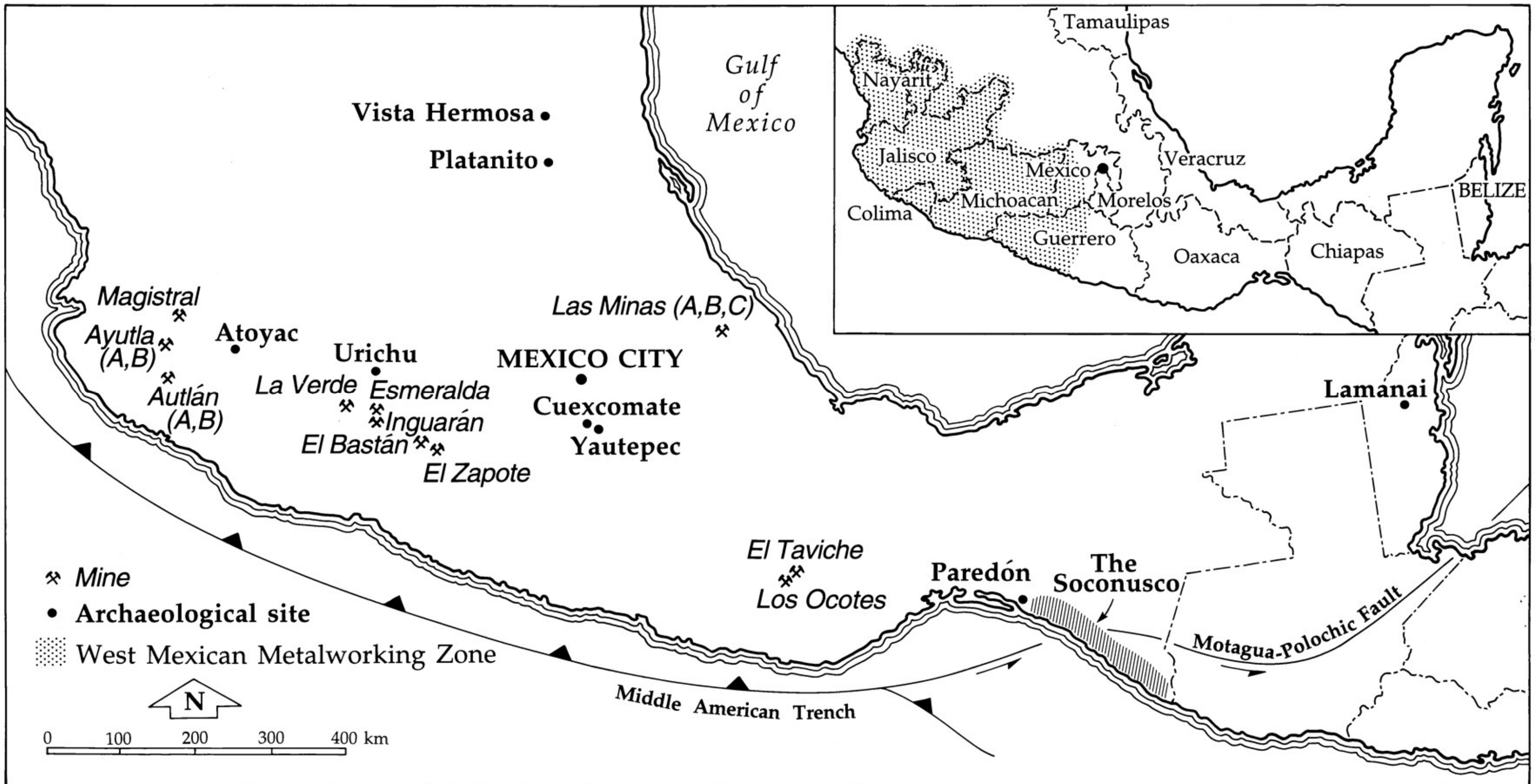
Extraction, usually by splitting the rock by fire and rock hammers, scraping the ores with horns or bones and carrying it out in sacks of hide.

Spanish reports (Garcilaso de la Vega) mention Inca mines with depths of 20 to 60 feet and a maximum of 240 feet.

The Inca state controlled the mines and exploited them with a form of forced labor called ***mita*** later adopted and enforced by the Spaniards.

Ores were mined for copper, tin, silver, gold and lead.

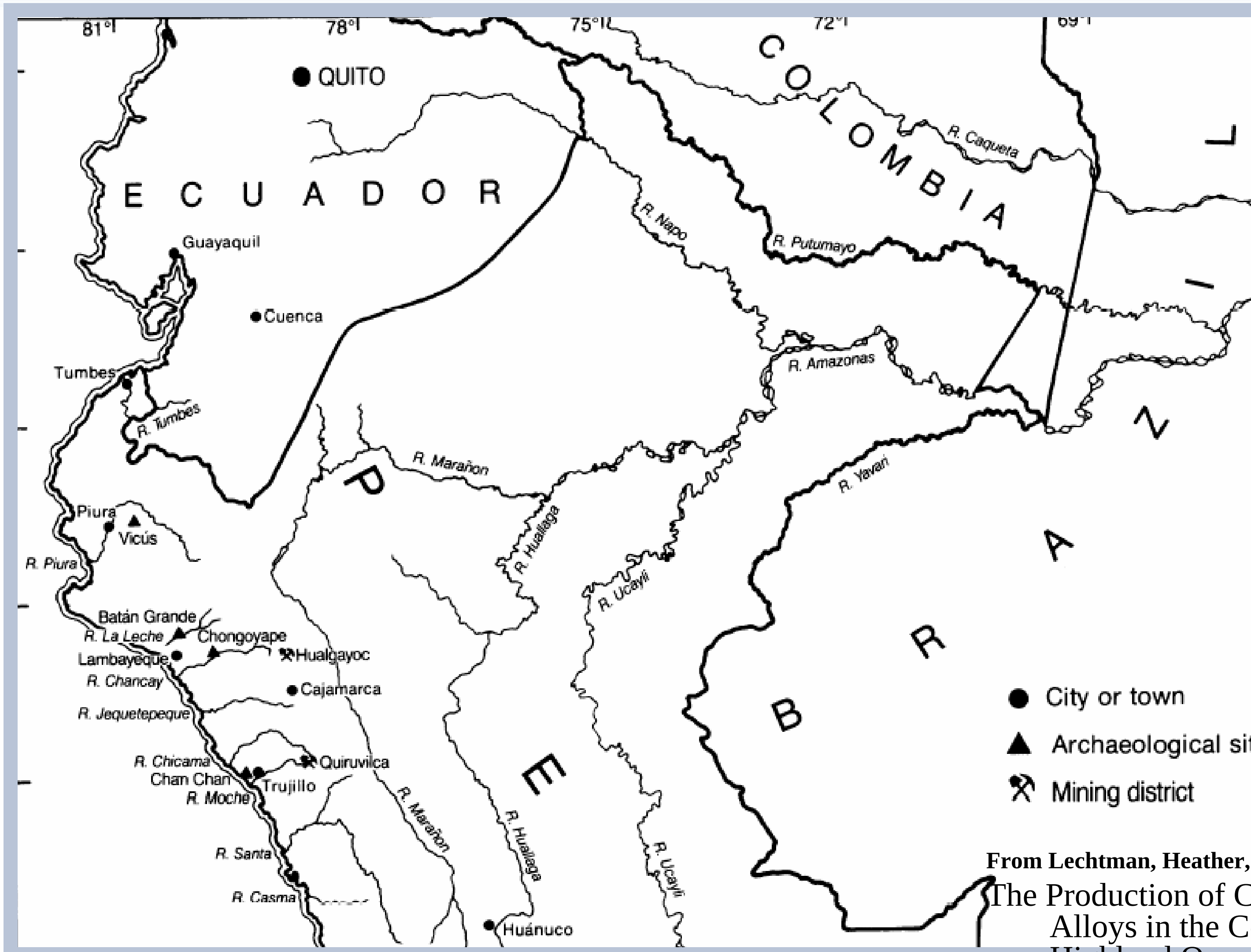
Copper mining in Mesoamerica



Copper ore sources exploited during 1300 to 1521 A.D.

Hosler,Dorothy1988

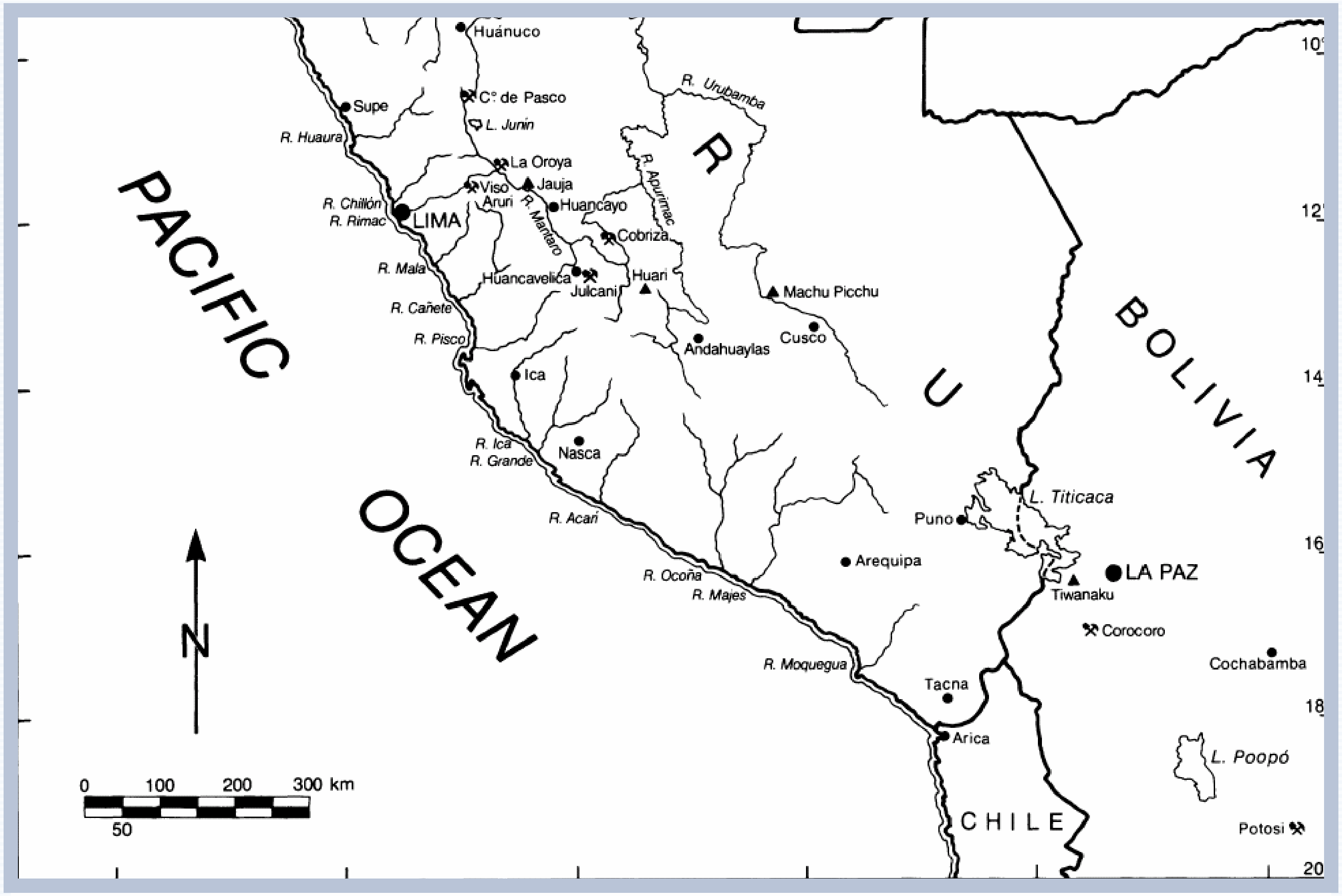
Pre-Columbian Andean Mines, North area



From Lechtman, Heather, 1991

The Production of Copper-Arsenic Alloys in the Central Andes: Highland Ores and Coastal Smelters.

Andean Mines South area



Metal working techniques

- Hammering and annealing
- Smelting: Huayrachinas
- Melting and casting
- Bronze production
- Sintering

Techniques: Hammering and annealing

Hammering involves only the shaping of the metal without melting. Gold is especially appropriate for using this techniques. One ounce of gold can be hammered into a 100 square-foot sheet, and also can be drawn into a wire five miles long.

Annealing is a process in which glass, metals, and other materials are treated to render them less brittle and more workable. Annealing consists of heating the material and then cooling it very slowly and uniformly. Annealing increases ductility and lessens the possibility of a failure by relieving internal strains. The process is also called hot working.

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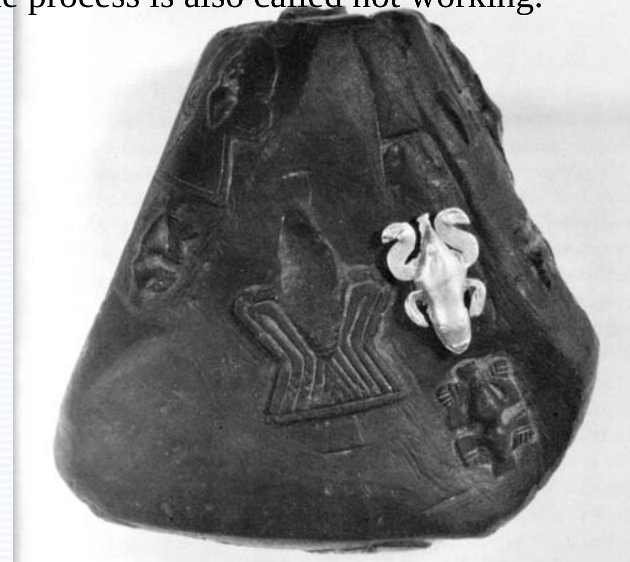


Black stone matrix used to make gold ornaments

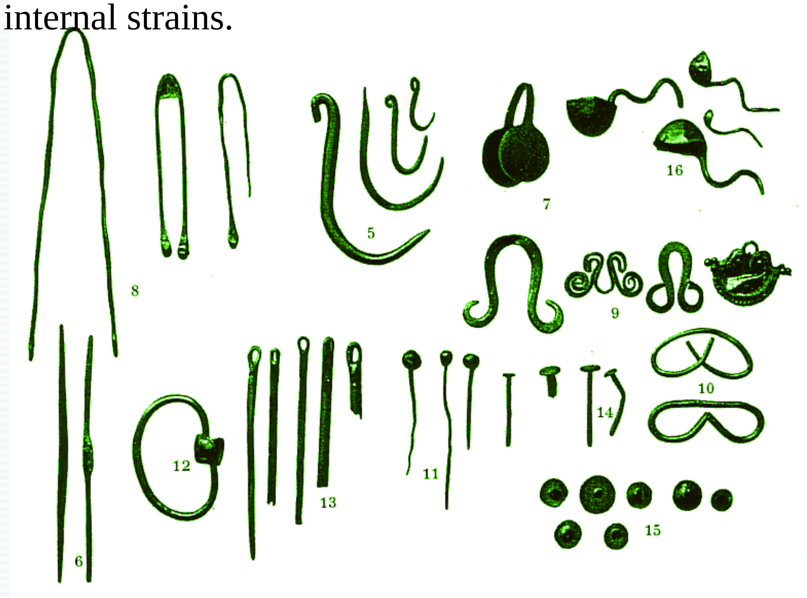


Fig. 5—16

From Bergsoe, 1937

Techniques

Vessel shaping by hammering

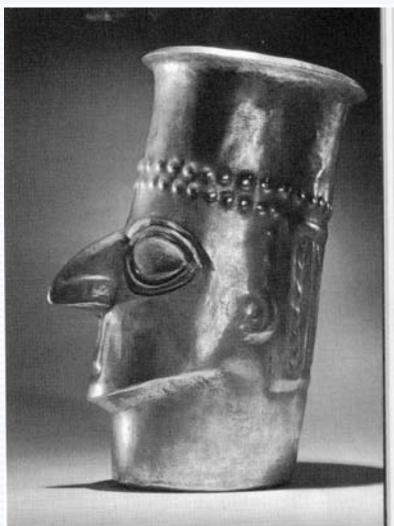
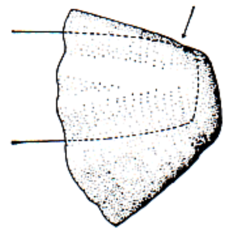


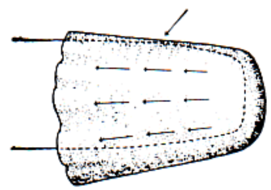
Fig. 39. *Chimú silver effigy beaker. Height: 8 in. Private coll.*

Fig. 40. *Chimú wooden model for hammered cup. Coll. Frederick Landmann, New York*

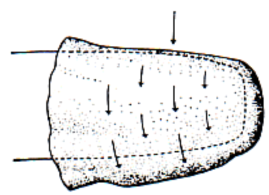
A. First step in shaping a vessel like the one shown in Fig. 39 is to sink the center of a thin sheet of gold in a concavity in the end of a log.



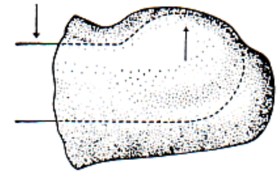
B. Here the metal has been placed over a piece of hardwood, and the first round or "course" of hammering has begun to raise the sides of the vessel.



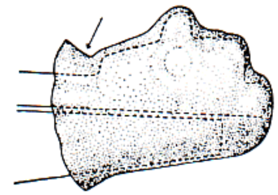
C. Still in position on the form, the metal is being stretched toward the mouth by hammering.



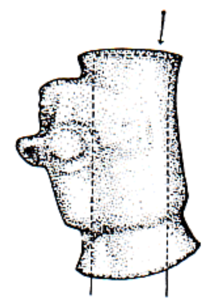
D. Continued hammering displaces the metal toward the front, where the face will be shaped in high relief.



E. Now on a new form, which would be called a snarling iron today, the bulge or "boss" for the face is being knocked out by repercussion with a springy anvil. The lefthand arrow shows where the form is struck. The righthand arrow indicates the force of repercussion.



F. A wedge is now placed behind a carved wood pattern, and the craftsman has begun to narrow the neck of the vessel at the arrow.



G. The final step: flattening the base of the beaker by hammering over a flat anvil.

Fig. 38. *Reconstruction by Dudley T. Easby, Jr., of steps followed in hammering out an effigy beaker like the one shown in Fig. 39. Drawings by Elizabeth K. Easby*

Smelting in Pre-Columbian times

Oxidized ores were the most used. In order to produce pure copper, Cu, from copper carbonate, $CuCO_3$ the atmosphere must be 'reducing'. That is, be high in carbon monoxide, CO.

Charcoal will burn to carbon monoxide, with sufficient air. This gives CO + $CuCO_3 = 2CO_2 + Cu$.

The use of huairas was only by the Incas.

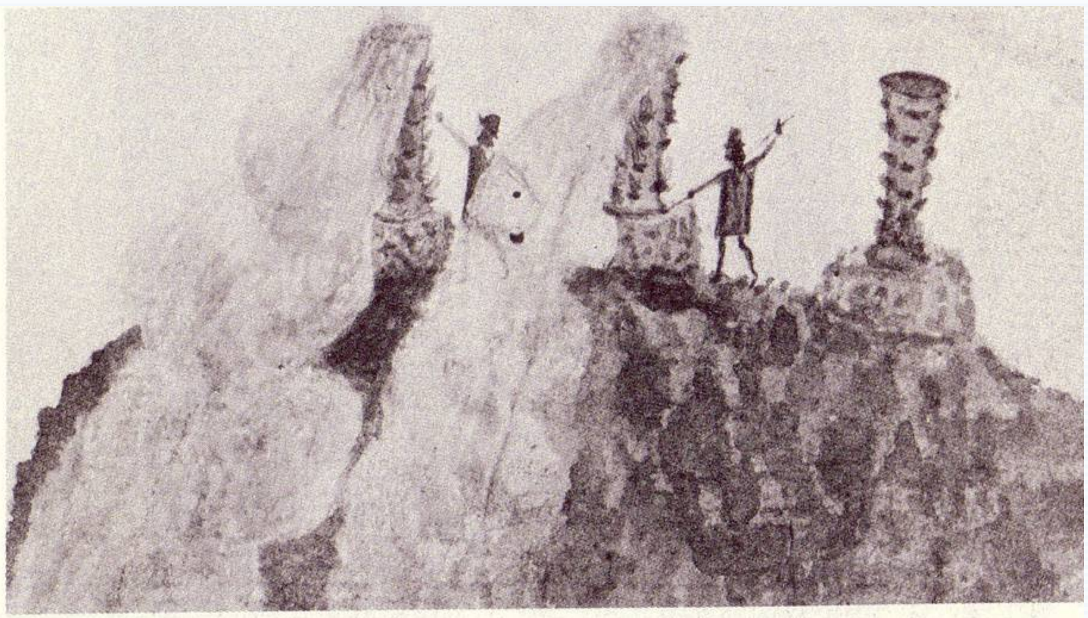


Figure 1. "Estos yndios estan guayrando." This illustration, probably from the late sixteenth century, shows two native refiners tending guayras. (The Hispanic Society of America, Atlas of Sea Charts (K3).)

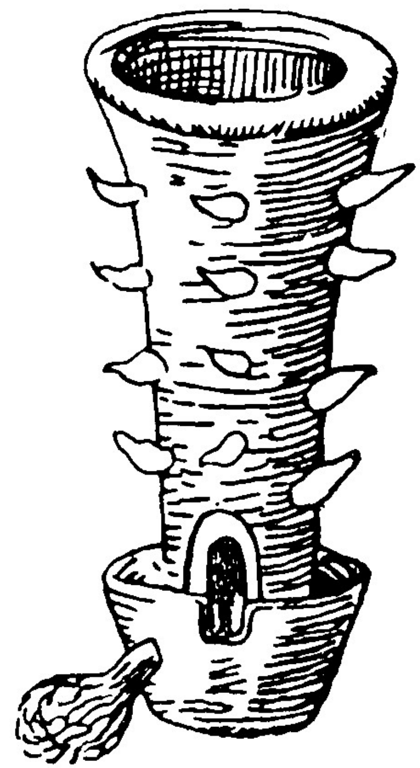


Fig. 189. Huaira *or casting furnace. Drawing after Barba 1929*

Huayrachinas

From Mary Van Buren

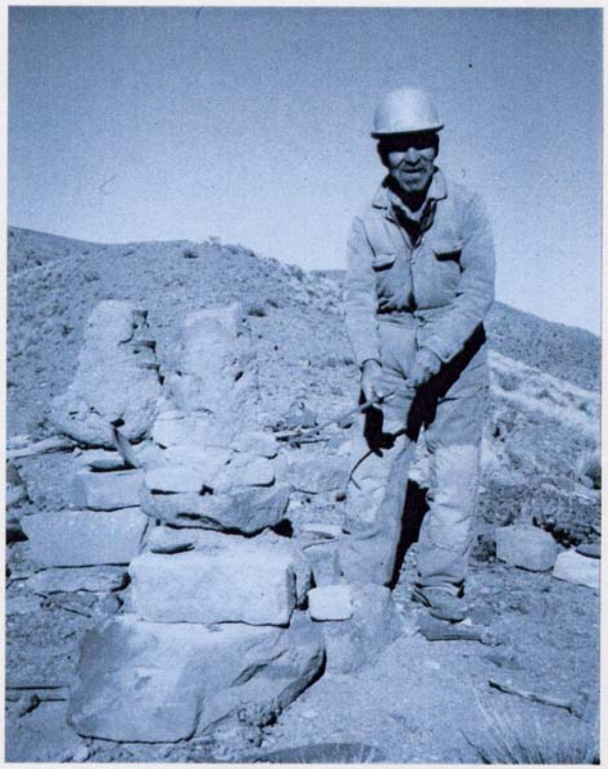


Figure 5. Carlos Cuiza smelting lead in a huayrachina.

It is charged from the top, with alternating layers of charcoal and ore. The molten metal flows out the bottom.

Melting and casting

AXE-BLADE CASTING as practiced in Mexico is depicted in Bernardino de Sahagún's study of pre-Columbian technology. Copper was brought to melting temperature with a blowpipe; the molten metal ran out of a furnace tap into a stone mold. On the ground is a finished axe blank; this will be given its final form by hammering (*see illustration below*).

Once the metal is purified it may be turned into something useful.

Fig. 193. *Black stone matrix used as a mold for making gold ornaments like the one in Fig. 194. Length: 8 in.* MAI

. 194. *Muisca cast-gold pectoral made a mold like the one shown in Fig. 193. ight: 5¾ in.* MDOB

From Emmerich, 1965

Lost wax casting

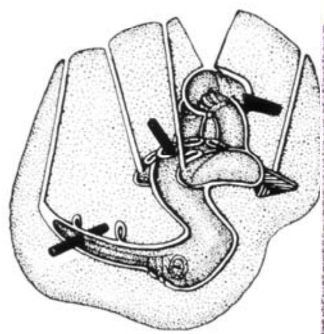
Fig. 90. *Sinú cast-gold deer finial. Height: 3½ in.* RWB

Fig. 91. *Sinú cast-gold owl effigy staff finial. Height: 4¾ in.* MPA

A. This rough core, made of clay mixed with charcoal, will be broken up and removed after casting, leaving the piece hollow inside. This saves gold and also permits the making of hollow vessels.

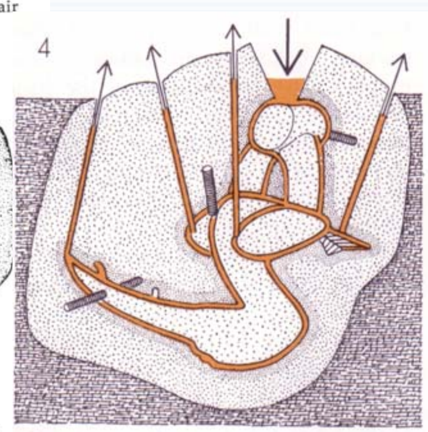
C. The casting will be done in an inverted position. Before enveloping the model in clay, a cone of wax is added to provide a pouring channel. And four wax rods have been added to provide air vents when the metal is poured in.

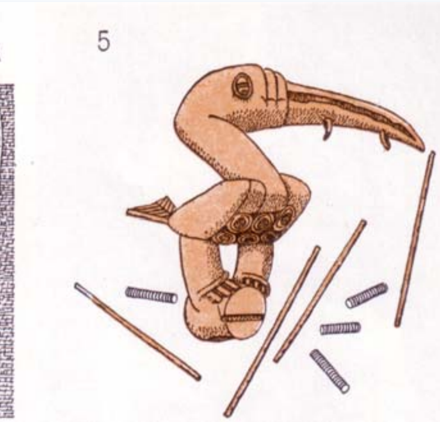
B. The rough core is first covered with a uniform coating of wax. The eyes, talons, suspension rings under the bill, and decorative holes have been added in the form of wax threads. The founder finishes the details on the wax model with sharp tools. The three black bars are the pegs to keep the core from slipping out of position during the work.



D. This drawing represents a section through the mold after the wax model has been melted out. The colored portion shows where the gold will flow between the shell and the core. It will rise into the air vents to form rods that will be later cut off and burnished. The core is finally broken and removed through the hollow bill and the holes in the breast and the back of the perch.

Fig. 92. *Reconstruction by Dudley T. Easby, Jr., of steps followed in casting a Sinú bird effigy staff finial. Drawings by Elizabeth K. Easby.*





Both Aztecs and Incas were using this technique

Bronze

- Bronze: is an alloy of copper, tin, arsenic, phosphorus, and small amounts of other elements.
- Bronzes are harder than brasses (copper and zinc), but much softer than iron.
- Most bronzes are produced by melting the copper and adding the desired amounts of arsenic, tin, phosphorous and other substances.

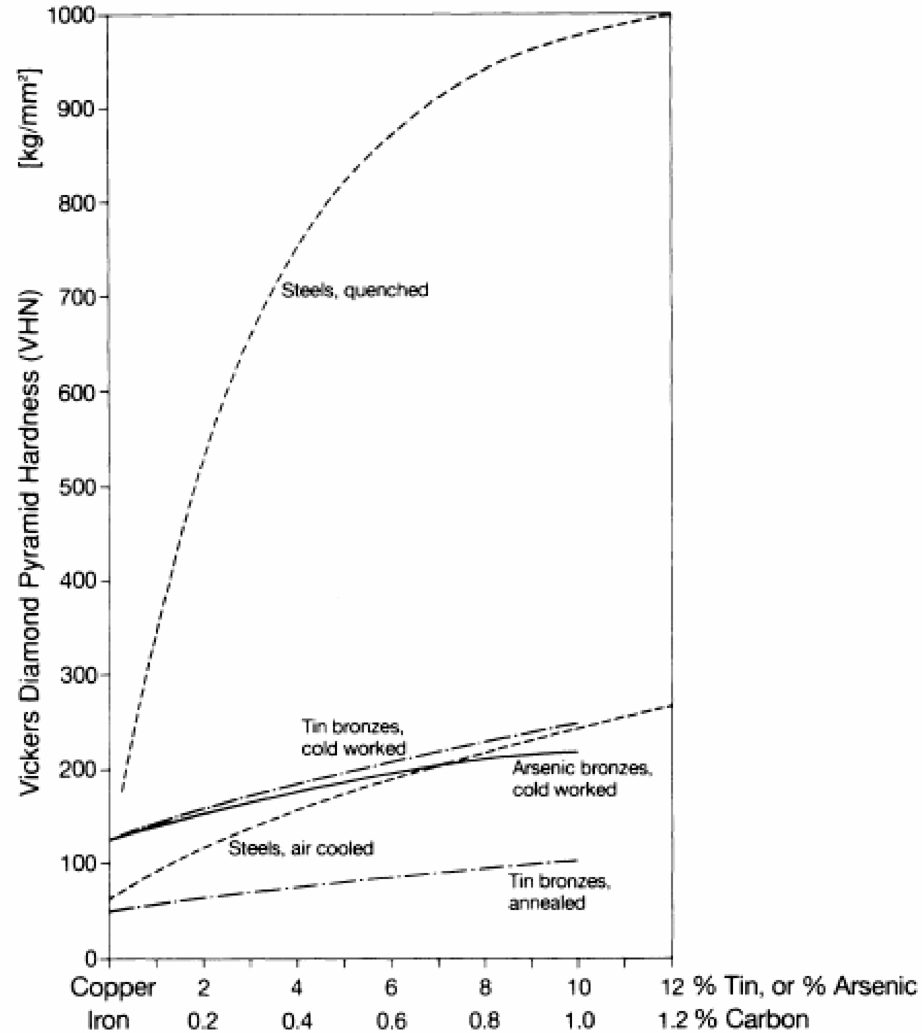


Figure 23. Curves illustrating the principal ways of hardening metal. The cold-worked arsenic bronzes and tin bronzes were reduced in thickness by 50%. They are somewhat harder than steels that have been heated and allowed to cool naturally. Quenched steels become dramatically harder than either of the bronzes. In relation to air-cooled steels, tin bronzes are only slightly harder than arsenic bronzes (after Smith 1967: fig. 39).

Pre-Columbian Bronzes

- Arsenic Bronzes: were produced in the Andes by 850 AD. Arsenic-bearing copper ores are very common in the region. The smelting of those ores produced naturally enriched arsenic bronzes. Batan Grande in Central Peru was a production center of this alloy with 24 furnaces uncovered so far.
- Tin bronzes: first appeared at 1000 AD in south Peru. Both bronzes were produced at the same time to use their different properties. The establishment of the Inca Empire at AD 1500 spread the use of this bronze from Chile to north Ecuador and west Mexico.
- Aztecs were producing bronzes about 1200 AD.

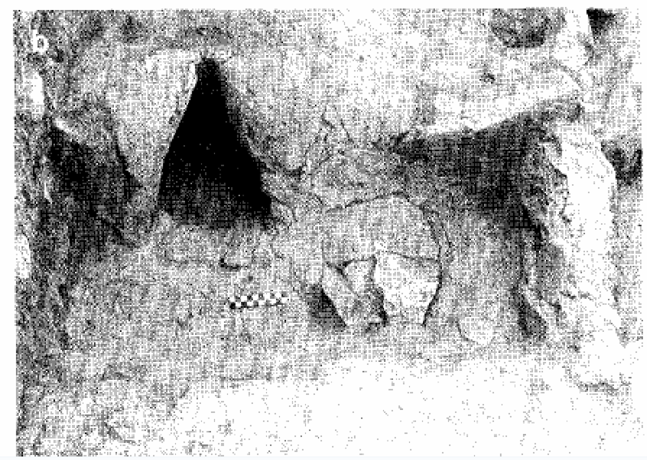


Diagram and photograph of a well preserved furnace, Shimada, Izumi, 1981. The Batan Grande-La Leche

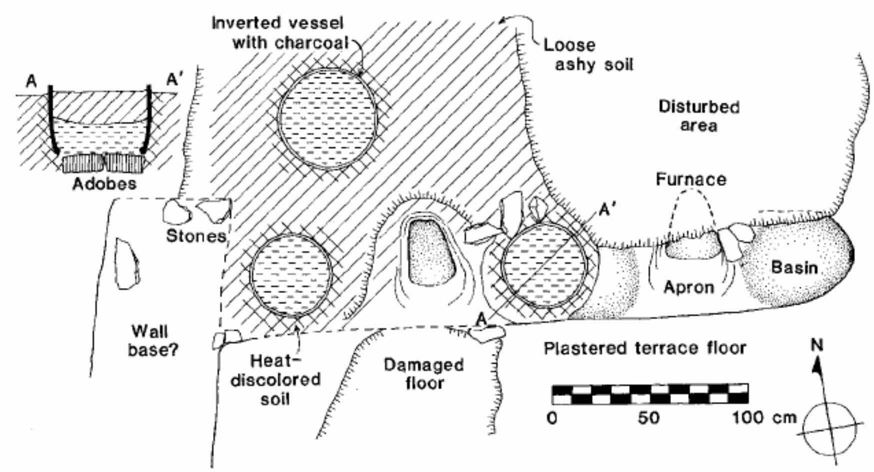


Fig. 6. Distribution of furnaces and inverted urns with charcoal contents in excavation area 4, sector III, Cerro de los Cementerios.

Platinum-Gold Sintering

Fig. 5—16

From Bergsoe, 1937

- Platinum has a very high melting point 1770 degrees Celsius, it was only reached by the technology of the industrial revolution.
- Materials from La Tolita (Ecuador) are made of gold and an alloy of gold and platinum. It was achieved not by melting the metals but by sintering (pressure and heat) applied to fine grains of platinum and gold to form a coherent mass without melting it.
- Sintering was a technique unknown in Europe at that time.

Chronology of metallurgy in the Andes

- 1500 -200 B.C. Earliest metals were native copper and gold.
- AD 200- 1000 Alloys: copper arsenic bronze.
- AD 850 copper- tin bronze in Southern Peru.
- Copper silver AD 1000
- AD 1500 copper- tin bronze spreads to all Inca Empire.

Mesoamerica - South America T

Spondilus princeps

- About AD 650 Mesoamericans acquire the first metal objects through trade with Ecuador and Colombia via maritime route. Trade of clam shells *(Spondilus)* was very active. The Incas used it for ritual practices, it only lives in warm waters, off Ecuador or areas north of it. This trade led to the adaptation of metal working

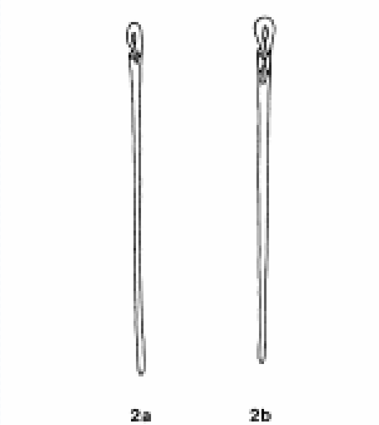


Figure 11
West Mexican loop-eye needles, types 2a and 2b.

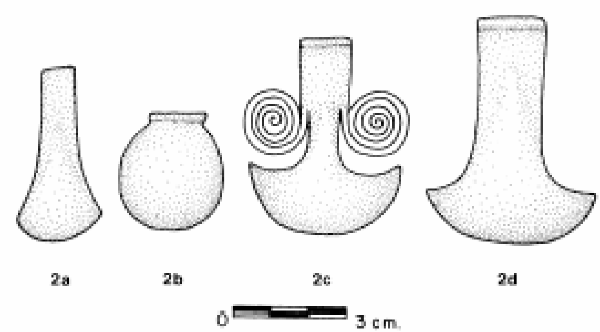


Figure 9
Shell design tweezers, West Mexico: Types 2a, 2b, 2c, 2d.

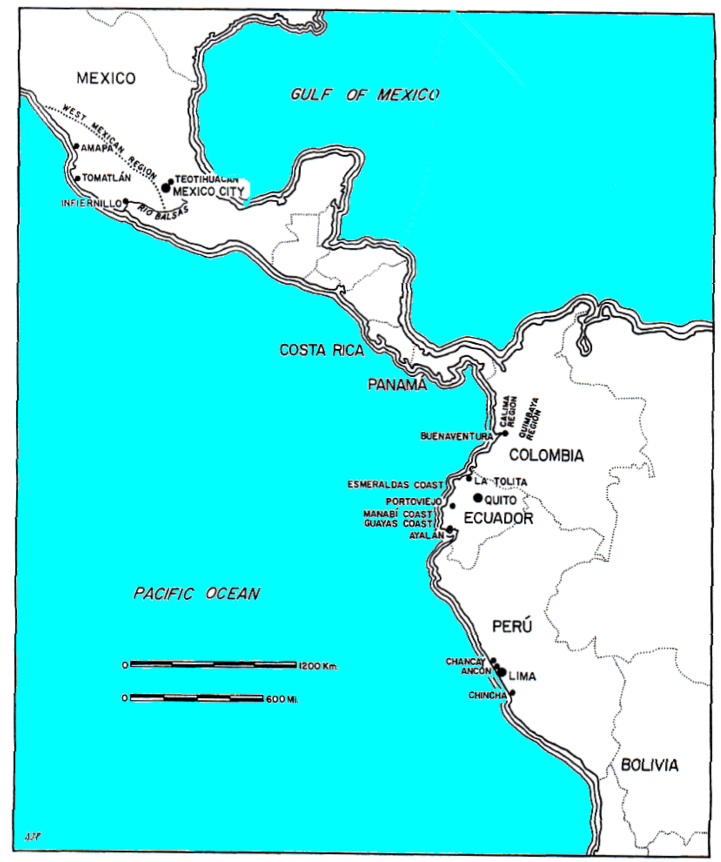
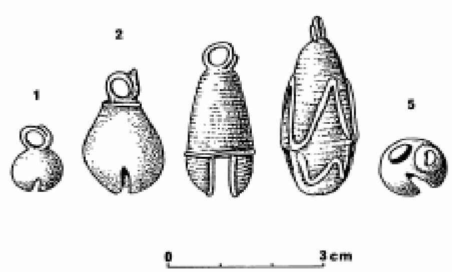


Figure 1
Map of geographical areas under discussion and sites and regions mentioned in text.

Mesoamerica area: Metallurgy

Figure 1 Map of Mesoamerica showing archaeological sites, the state boundaries in western Mexico and the limits of the West Mexican metal-working zone. Courtesy of MIT Press.



ig. 4. Vista Hermosa and Platan- › bell subtypes. Subtypes 1, 3, and 4 appear at Vista Hermosa; subtypes 1 to 5 at Platanito.

- **Metallurgy Initial Period** AD 800 –AD 1200 similar techniques to Ecuador and Colombia
- **Metallurgy Second Period** of West Mexican metallurgy (A.D. 1200-1300 to the Spanish invasion) new techniques from these same regional metallurgies were developed, in addition to technical components from the metallurgy of Peru.
- Bronzes with high percentages of tin and arsenic (10 -12 %) to achieve golden and silvery colors.

Pre Colombian Mesoamerica metallurgy

Fig. 2. Mesoamerican sites and regions cited in text.

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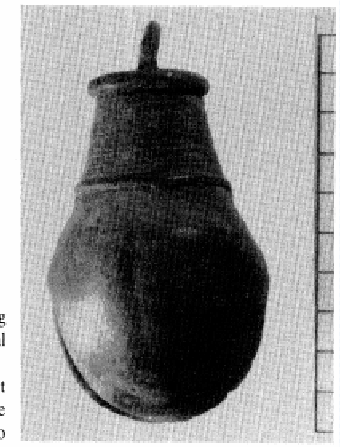
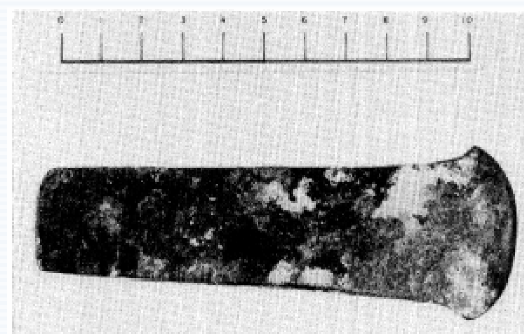


Plate 1 Period 1 copper bells from West Mexico cast using the lost-wax method. From the collections of the Regional Museum of Guadalajara, Guadalajara, Jalisco Mexico.
Plate 2 (right) Period 1 copper bell from West Mexico cast using the lost-wax method. From the collections of the Regional Museum of Guadalajara, Guadalajara, Jalisco Mexico.



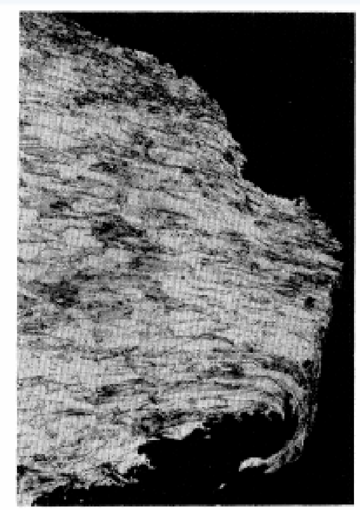


Plate 3 Period 1 copper axe from West Mexico. From the collections of the Regional Museum of Guadalajara, Guadalajara, Jalisco Mexico.
Plate 4 (right) Longitudinal sample from blade tip of a Period 1 copper axe. Elongated and compressed grains reveal heavy cold work and the extreme tip shows deformation from use (mag. 50×).