Scientific Research Publishing

Archaeological Discovery, 2025, 13(2), 49-58
https://www.scirp.org/journal/ad
ISSN Online: 2331-1967
ISSN Print: 2331-1959

The Ancient Quimbalete and Mercury Efficiency in Present-Day Small-Scale Gold Processing, Perú

William E. Brooks

Geologist, Reston, USA
Email: webgeology@aim.com

How to cite this paper: Brooks, W. E. (2025). The Ancient Quimbalete and Mercury Efficiency in Present-Day Small-Scale Gold Processing, Perú. *Archaeological Discovery, 13,* 49-58.
https://doi.org/10.4236/ad.2025.132003

Received: January 8, 2025
Accepted: February 25, 2025
Published: February 28, 2025

Abstract

The *quimbalete* was used in pre-contact Perú and is still used today to process gold. It is a 1 - 2 ton, manually operated, artisanal stone crushing device used to release the gold from the ore as it is rocked back and forth on a water-lubricated, stone base to which mercury is added. The weight and the back-and-forth rocking motion forces the mm-sized gold grains and mercury together to form an amalgam that is recovered from the muddy slurry and then burned to produce an anthropogenic gold nugget. Spot geochemical sampling of: 1) the Au ore, 2) post-amalgamation mud, and 3) dried post-cyanide mud indicate that the ages-old mercury amalgamation process captures ~20% of the gold from the crushed ore and sodium cyanide is the final step to capture the remaining gold. Therefore, since mercury is used with *quimbaletes* to amalgamate gold at small-scale gold processing sites today in Perú, then, the documented use of *quimbaletes* in pre-contact Perú is evidence for and consistent with pre-contact use of mercury for gold amalgamation.

Keywords

Quimbalete, Gold, Amalgamation, Comminution, Perú

1. Introduction

The ancient *quimbalete*, or Inka mill, is a stone crushing device that dates to ancient time in the Andes and is still used today, mainly in artisanal mining in Perú and Bolivia. Its purpose is comminution, or crushing and pulverizing the ore, thereby releasing the gold for separation, chemical treatment, and recovery (Thrush, 1968). Jaw crushers have a similar role in ore processing in Perú's present-day large-scale open-pit copper-gold mines.

The *quimbalete*, also called a *bimbalete* or *bambalete*, which comes from an indigenous word meaning shake or move from one side to the other while staying in the same place. The terms *piruro* or drum-wheel (Petersen, 1970/2010) or *maray* (de Nigris and Riart, 2013) may be also used for pre-contact artisanal stone crushers. The *quimbalete* consists of two parts, a lower stationary base of granite or possibly metamorphosed rock and an upper, larger movable block of similar composition. The upper block is rocked back and forth either by walking or by rocking the *quimbalete* by hand with one or two strong wooden poles that are attached on either side. The upper movable part, which may weigh 1 - 2 tons, may be a block, or shaped like a truncated pyramid, or crescent-shaped. It may be ~1 m high and ~0.5 m wide, and can be very simple or elaborate; however, smaller versions called *molinetes* that are foot-operated from a seated position are used in northern Perú (Larco Hoyle, 2001). Water is added at the base to lubricate the blocks and help the initial gravity separation of the heavier gold from the waste rock. Mercury is then added to the muddy slurry at the base to selectively amalgamate the mm-sized gold grains. Because of the use of mercury and its toxicity (Brooks et al., 2007; Chauvin, 2018), the work takes place outdoors with only loosely constructed thatch or wooden walls and a roof above the worker who rocks the *quimbalete* by foot (**Figure 1**).

Figure 1. Quimbalete and quimbalete worker.

Descriptions and figures of artisanal crushers and ancient *quimbaletes* are numerous, for example: Agricola (1556/1912); Atlas (2000); Barba (1640); Bargalló (1955, 1969); Costa et al. (2009); Olaechea (1901); Petersen (1970/2010); Rivero y Ustariz (1857); and Romaña (1908). Pre-contact artisanal crushers have been found at ancient mining sites in Argentina, Bolivia, Chile, and Perú (Ahlfeld & Schneider-Scherbina, 1964; Larco Hoyle, 2001; Petersen, 1970/2010). Descriptions and locations of many types of ancient and modern artisanal crushers used in the Andes are provided in de Nigris and Riart (2013) and a stone mill of similar proportions and function was found at the ancient mining site of Gümüsköy, Türkiye (Kaptan, 1982).

2. Mercury and Gold Processing in Perú

The Principle of Uniformitarianism, also known as the Present is Key to the Past, was proposed by Lyell in the 19th century and application of this principle helps understand pre-contact gold processing by study of methods used today, in particular, the use of mercury with the *quimbalete*. The importance of mercury for ancient gold mining in Perú was described by Larco Hoyle (2001) "*...el beneficio de oro es todavía primitivo…fue el mismo que emplearon los antiguos peruanos, incluyendo el empleo del azogue, que fue usado desde muy remota antigüedad*" [...gold processing is still primitive…and was the same used by ancient Peruvians including the use of mercury which was used since very ancient time]. Geochemical evidence for pre-contact use of mercury for gold amalgamation is based on comparison of the high mercury content of pre-cursor alluvial gold (>5000 ppm Hg) and the lower mercury content of artifact gold (<20 ppm Hg) resulting from burning (*refogado*) the gold-mercury amalgam to volatilize the mercury (Petersen, 1970/2010; Brooks et al., 2013). The common ore of mercury, cinnabar (HgS) is widely available in Perú, and the two most well-known occurrences are Huancavelica and Chonta (Arana, 1901; Brooks, 2023; Garbín, 1904; Giles, 1990; Noble and Vidal, 1990; Petersen, 1970/2010; Yates et al., 1955).

Industrial amounts of gold are produced in only two ways: 1) gravity separation, first by washing and then addition of mercury (amalgamation) and 2) use of sodium cyanide (Craig and others, 2001). Since sodium cyanide (NaCN) was not used in mining until the late 1880s, then chronologically the use of mercury must be considered as an important part of the mining technology that produced prodigious amounts of gold from alluvial sources in Gold Rush, California, ancient Perú, or at the 1st century BC Roman alluvial gold mining site of Las Médulas, Spain (Fernández-Lozano et al., 2021). Other methods include the legendary Golden Fleece, as well as variances in Perú that use carpet, sheep or other animal skins; however, all rely on the high specific gravity of gold to first concentrate the gold in water (Healy, 1979). Another is "dry washing" which is also known as the *aventadero* method in which air or wind is used to separate the heavier gold from the lighter minerals, much like grain is separated from chaff (Petersen, 1970/2010). In Chocó, western Colombia, plant juices are added to water in place of mercury to concentrate the gold (Brooks et al., 2015). Plants are also used with the smaller *molinetes* at Santa Clara de Tulpo, northern Perú as a part of the gold processing (Larco Hoyle, 2001); however, none of the above methods are widely used.

Perú is the leading gold producer in South America and during 2007-2011, Perú produced ~150 tons of gold annually from its large-scale, open-pit gold-copper mines that use cyanide. During the same time period 16 - 22 tons of gold were produced annually from small-scale alluvial gold mines, mainly in Madre de Dios in southeastern Perú, that use mercury amalgamation (Gurmendi, 2012). Other important alluvial gold districts include Marañon in northeastern Perú and Rio Huallaga in east-central Perú (Noble and Vidal, 1994; Atlas, 1999). Approximately 1.5 tons of gold per month are produced from Perú's small-scale alluvial gold mines that use the ages-old technique of gravity separation and mercury amalgamation (Ahern, 2016; Al-Hassan and Hill, 1986; Brooks et al., 2007; Cánepa, 2005; Chauvin, 2018; Soto-Viruet, 2018). These alluvial gold sources likely provided the gold used by Atahualpa as ransom for his release from the Spanish before his execution in 1533.

3. The Quimbalete Process

The first step in the *quimbalete* process, crushing the ore, is mechanical and the following steps that include the addition of mercury and later, cyanide are chemical.

Figure 2. Semi-dried mud in settling tank.

Gold ore is first brought to the *quimbalete* site for processing and then the ore is crushed in the *quimbalete* with water and mercury added at the base. After crushing, the gold-mercury amalgam is recovered and squeezed through a cloth to remove excess mercury for reuse. The miner is paid for the gold after the mercury-gold amalgam is burned (*refogado*) with a gas torch to remove the mercury (Brooks et al., 2007; Cánepa, 2005) and weighed. The mud from the *quimbalete* goes on to a settling tank where the water evaporates or is drained and the semi-dried mud (**Figure 2**) is removed and transported to a plastic-lined cyanide leach field. Approximately 20% of the gold in the ore is recovered as a gold-mercury amalgam during the initial *quimbalete* processing; however, the semi-dried gold-bearing mud is then treated with cyanide to recover the remaining gold in solution. After application of cyanide the site owner treats the gold-bearing pregnant solution for final gold recovery.

The importance of cyanide as a follow-up to ages-old mercury amalgamation is demonstrated by an example of artisanal gold processing in Aruba. Gold was discovered in 1824 and was recovered from alluvial and vein deposits using crushing, gravity separation, and mercury amalgamation until ~1880 when profits declined and mining ceased. Then, in 1897 the cyanide method for gold recovery was introduced, mining resumed profitably, and continued until ~1916 (Gold Mine Ranch, 2021).

4. Site Sampling

Two *quimbalete* sites in Perú, El Ingenio and Portachuelo, were sampled to determine the efficiency of mercury amalgamation and the follow-up cyanide process; however, the owners requested that the exact location of these sites and other details not be given. After recovery of the amalgam the sludge goes on to the settling tanks and is mixed with ongoing sludge from other *quimbaletes* operating at the site. It is important to indicate that the *quimbalete* and subsequent processes are ongoing with no clean-up other than perhaps a spray with a hose after the amalgam is removed. There is no continuity between samples of: 1) ore, 2) muddy mercury-bearing sludge, and 3) cyanide-treated mud given on **Table 1** and **Table 2**. Spot samples were taken at each step given below:

Step 1: ore is crushed by the *quimbalete*, ~20% of the gold, as amalgam, is removed using mercury during this step.

Step 2: mud from step 1 goes to settling tanks to dry.

Step 3: dried mud from the settling tanks is transported to the plastic-lined cyanide leach pad for cyanide recovery of the remaining gold.

The sludge from the first step is mixed with sludge from several other *quimbaletes* operating at the sites and, similarly, the material in the cyanide leach pad is mixed with ongoing material input. The spot samples obtained from each step of the process were analyzed by ICP (Inductively Coupled Plasma) and fire-assay for gold content. Results from the two sites are given in **Table 1** and **Table 2**, respectively.

Table 1. Quimbalete geochemical sampling, El Ingenio, Perú.

	PE241 Au ore	PE242 Au ore	PE243 after Hg	PE244 after Hg	PE245 after NaCN	PE246 after NaCN
Au (0.003)	53.5	14.9	22.5	34.9	<0.5	<0.5
Ag (0.3)	1.8	2.0	11.2	14.2	9	9.4
Al (300)	4201	2160	11,127	12,180	29,781	29,480
As (2.0)	25	28	3349	4300	1665	1692
Bi (5.0)	<5	<5	66	154	36	35
Ca (300.0)	1304	797	9199	22,712	23,972	23,961
Ce (1.0)	10	3	7	7	13	13
Co (1.0)	9	7	189	217	33	32
Cu (1.0)	13	3891	1565	1770	2382	2292
Fe (300)	10,894	13,379	165,214	194,570	91,595	92,382
Hg (0.5)	<0.5	2.6	>100	>100	57.1	60.6
K (300)	<300	<300	2600	2304	9787	9857
La (1.0)	6	3	7	11	8	8
Li (2.0)	3	<2	3	4	7	7
Mg (100.0)	3655	1361	2366	3379	4419	4418
Mn (5.0)	182	175	559	715	662	616
Na (100)	207	236	1017	1157	3915	4068
Ni (1.0)	11	13	17	28	17	17
Pb (3.0)	4	6	2339	2861	4340	4354
S (30)	112	3329	16,930	19,336	3215	3173
Sb (2.0)	<2	<2	11	15	9	8
Sc (1.0)	<1	<1	3	4	7	7
V (3.0)	11	4	284	269	155	150
Zn (3.0)	7	129	515	839	545	532

Multi-element ICP analyses in parts per million (detection limit given to right of element, in parentheses); American Assay, Sparks, NV [ICP-I04AB28, Au-fire assay]. Sample Descriptions: PE241 Au ore, Fe-stained milky quartz; PE242 Au ore, Fe-stained milky quartz; PE243 dried mud after *quimbalete* crushing, water, and amalgamation with mercury; PE244 dried mud after *quimbalete* crushing, water, and amalgamation with mercury; PE245 dried mud after cyanide treatment; PE246 dried mud after cyanide treatment.

Table 2. Quimbalete geochemical sampling, Portachuelo, Perú.

	PE247 Au ore	PE248 Au ore	PE249 after Hg	PE2410 after Hg	PE2411 after NaCN	PE2412 after NaCN
Au (0.003)	3.1	13.0	7.6	2.1	1.2	1.1
Ag (0.3)	34.7	289.1	16	4.2	4.5	4.5
Al (300)	32,775	33,359	25,665	20,947	30,844	31,330

Continued

As (2.0)	453	1300	528	262	1164	897
Bi (5.0)	<5	<5	18	<5	31	26
Ca (300.0)	13,226	11,876	33,824	18,977	49,135	63,155
Ce (1.0)	13	9	9	3	14	16
Co (1.0)	317	1044	47	68	23	20
Cu (1.0)	59,015	30,812	1715	8786	2173	1729
Fe (300)	13,147	118,846	56,822	61,812	62,871	60,382
Hg (0.5)	<0.5	<0.5	125.5	116.6	46.8	39.8
K (300)	6519	6853	7368	4058	8973	9590
La (1.0)	9	7	6	4	9	10
Li (2.0)	10	11	8	12	10	10
Mg (100.0)	5121	5371	12,830	10,549	5699	5321
Mn (5.0)	1021	821	820	647	601	556
Na (100)	4621	3791	1709	705	4755	5053
Ni (1.0)	65	75	12	22	20	21
Pb (3.0)	71	94	956	78	1085	1251
S (30)	30,479	17,910	7485	3734	3643	4964
Sb (2.0)	5	3	<2	<2	4	3
Sc (1.0)	12	11	8	8	8	7
V (3.0)	78	74	86	108	160	179
Zn (3.0)	332	140	272	121	548	515

Multi-element ICP analyses in parts per million (detection limit given to right of element, in parentheses); American Assay, Sparks, NV [ICP-I04AB28, Au-fire assay]. Sample Descriptions: PE247 Au ore, Fe-stained quartz vein; PE248 Au ore, black-rusty Fe-stained quartz vein; PE249 dried mud after *quimbalete* crushing, water, and amalgamation with mercury; PE2410 dried mud after *quimbalete* crushing, water, and amalgamation with mercury; PE2411 dried mud after cyanide treatment; PE2412 dried mud after cyanide treatment.

5. Elements of Interest

Gold—Four spot samples of gold-bearing ore were sampled and the gold content of the samples ranged from 53.5 - 3.1 ppm gold for an average gold content of 21.1 ppm gold (**Table 1**, **Table 2**). After amalgamation spot samples ranged from 34.9 - 2.1 ppm gold for an average gold content of 16.7 ppm gold indicating that mercury efficiency yielded ~20% of the gold during amalgamation. Gold content of four spot samples after cyanide treatment ranged from <0.5 - 1.2 ppm gold for an average 0.8 ppm gold content resulting in cyanide efficiency of ~99% in removal of the gold.

Silver—Four spot samples of gold-bearing ore were sampled and the silver content of the samples ranged from 289.1 - 1.8 ppm silver for an average silver content of 81.9 ppm silver (**Table 1**, **Table 2**). After amalgamation spot samples ranged from 16 - 4.2 ppm silver for an average silver content of 11.4 ppm silver. No conclusion can be reached regarding the efficiency of silver removal by mercury because of possible contamination of the mercury with silver and variance of initial silver content in the ore samples as indicated by the anomalously high silver content of one ore sample. However, average silver content after amalgamation of the spot samples was 11.4 ppm silver. Silver content of four spot samples after cyanide treatment ranged from 9.4 - 4.5 ppm silver for an average 6.8 ppm silver content and cyanide efficiency of ~99% in removal of silver.

Mercury—Four spot samples of gold-bearing ore contained an average of 1 ppm mercury. After amalgamation the spot samples predictably were much higher in average mercury content of >100 ppm remnant mercury in the sludge. After cyanide treatment the samples contained an average of approximately 51 ppm mercury indicating that cyanide is not efficient in removing mercury from the processed material as it is with the precious metals. However, nitric acid can be used to remove mercury from gold-bearing sediments (Topkaya, 1984).

6. Conclusion

An understanding of present-day gold processing methods is key to understanding gold processing in the past, specifically the use of the *quimbalete*. Perú, the leading gold producer in South America, produced ~150 tons of gold annually from its large-scale, open-pit mines that use cyanide during 2007-2011. During the same time period 16 - 22 tons of gold were produced annually from small-scale alluvial gold mines, mainly in Madre de Dios, that use mercury amalgamation (Gurmendi, 2012). Approximately 1.5 tons of gold per month are produced from Perú's from small-scale alluvial gold mines that use ages-old indigenous technology of *quimbaletes*, gravity separation in water, and mercury amalgamation (Ahern, 2016; Brooks et al., 2007; Cánepa, 2005; Chauvin, 2018; Soto-Viruet, 2018). Mercury used in the *quimbalete* process removes ~20% of the gold and the remaining material is treated with cyanide for 99% removal of the gold. Since cyanide was not available in ancient time, then indigenous *quimbalete* technology and the use of mercury is key to understanding pre-contact gold production. Present-day *quimbalete*-mercury technology continues to provide gold to modern Perú's commodity market much as that ancient technology, which was used before European contact, provided some of the gold for artifact production in pre-contact Perú.

Acknowledgements

My respect and gratitude to Dr. Georg Petersen (deceased), University of Kiel, Germany and Lima, Perú for leading the way in the application of geology and geochemistry to archaeology in Perú by his publication of *Minería y Metalurgia en el Antiguo Perú* [Mining and Metallurgy in Ancient Perú]. Sincere thanks are expressed to Sr. Christian Ormeño for transport, security, and help in the field.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

References

Agricola, G. (1556/1912). De Re Metallica (Trans. by H. C. Hoover & H. L. Hoover, p. 638). Kessinger Publishing. [Book VIII, pp. 298-299]

Ahern, N. (2016). Mercury in Gold Processing. In M. D. Adams, (Ed.), *Gold Ore Processing* (2nd ed., pp. 753-766). Elsevier. https://doi.org/10.1016/b978-0-444-63658-4.00042-6

Ahlfeld, F., & Schneider-Scherbina, A. (1964). *Los yacimientos minerales y de hidrocarburos de Bolivia* (p. 388). La Paz, Ministerio de Minas y Petroleo, Departamento Nacional de Geología, Boletin No. 5 (Especial).

Al-Hassan, A. Y., & Hill, D. R. (1986). *Islamic Technology: An Illustrated History* (p. 304). Cambridge University Press.

Arana, P. P. (1901). *Las minas de azogue del Perú* (p. 109). Imprenta El Lucero.

Atlas (1999). *Mining and Energy in Peru* (J. Mendoza, ed., p. 111). Ministry of Energy and Mines, Dirección General de Minería, Republica del Perú.

Atlas (2000). *Atlas de la pequeña minería en el Perú* (J. Charmot Sarmiento, ed., p. 88). Minis-terio de Energía y Minas, Dirección General de Minería, Republica del Perú.

Barba, A. A. (1640). *El arte de los metales* (Trans. by R. E. Douglass, & E. P. Mathewson). John Wiley & Sons.

Bargalló, M. (1955). *La mineria y metalurgia en la América española durante la época colonial: México, Comp.* Fundidora de Fierro y Acero de Monterrey.

Bargalló, M. (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.

Brooks, W. E. (2023). Enigma of Alluvial Gold Mining in Pre-Contact Peru—The Present Is Key to the Past. *Archaeological Discovery, 11,* 39-64. https://doi.org/10.4236/ad.2023.112003

Brooks, W. E., Sandoval, E., Yepez, M., & Howard, H. (2007). *Peru Mercury Inventory 2006: U.S. Geological Survey Open-File Report 2007-1252.* http://pubs.usgs.gov/of/2007/1252/

Brooks, W. E., Schwörbel, G., & Castillo, L. E. (2013). Amalgamation and Small-Scale Gold Mining in the Ancient Andes. In N. Tripcevich, & K. Vaughn (Eds.), *Mining and Quarrying in the Ancient Andes* (pp. 213-229). Springer. https://doi.org/10.1007/978-1-4614-5200-3_10

Brooks, W. E., Sierra-Giraldo, J. A., & Palacios, F. M. (2015). Green Gold-Dirty Gold, Tadó, Dept. Chocó, Colombia. *Natural Resources, 6,* 534-542. https://doi.org/10.4236/nr.2015.611051

Cánepa, C. (2005). *Minería a pequeña escala en la Costa Sur Media del Perú* (p. 62). Instituto Geo-lógico Minero y Metalúrgico, INGEMMET Boletín 3, Serie E.

Chauvin, L. (2018). *Pope Brings Environmental Crusade to Peru* (p. A8). Washington Post.

Costa, M., Alfonso, P., & Palacios, S. (2009). Proceso de tratamiento para la recuperacion de oro en el asentiamiento minero artisanal de Misky, Perú. In *Segundo Congreso Internacional Sobre Geologia Y Minería En La Ordinación del Territorio y en el Desarrollo, Utrillas* (pp. 231-242). Academia. https://www.academia.edu/70426845/proceso_de_tratamento_para_la_recuperacion_de_oro_en_el_asentiamiento_minero_artesanal_de_Misky_Peru

Craig, J. R., Vaughan, D. J., & Skinner, B. J. (2001). *Resources of the Earth* (p. 520). Prentice-Hall.

de Nigris, M. R., & Riart, O. P. (2013). Molinos mineros de tradición andina. *De Re Metallica, 20,* 1-12. Sociedad Española para la Defensa de Patrimonio Geológico y Minero.

Fernández-Lozano, J., Nsue Nnandong, A., Rivera, S., Esbrí, J. M., Carrasco, R. M., Pedraza, J. et al. (2021). Uso de mercurio para el beneficio de yacimientos secundarios de oro en época romana. ¿Realidad o ficción? *Geogaceta, 69,* 75-78. https://doi.org/10.55407/geogaceta102452

Garbín, L. (1904). Apuntes sobre los minerales de Huallanca, Chonta y Queropalca. *Boletin de la Sociedad de Ingenieros, VI,* 1-17.

Giles, C. F. (1990). *Minas de mercurio conocidas en el Peru* (p. 3). INGEMMET Archivo Tecnico, Codigo 9921.

Gold Mine Ranch (2021). *The Gold Mine Ranch History, Aruba.* https://www.thegoldmineranch.com/history

Gurmendi, A. C. (2012). *The Mineral Industry of Peru: U.S. Geological Survey 2012 Minerals Yearbook.* https://minerals.usgs.gov/minerals/pubs/country/2012/myb3-2012-peru.pdf

Healy, J. F. (1979). Mining and Processing Gold Ores in the Ancient World. *JOM, 31,* 11-16. https://doi.org/10.1007/bf03354474

Kaptan, E. (1982). New Discoveries in the Mining History of Turkey in the Neighborhood of Gümüsköy and Kütahya. *Bulletin of the Mineral Research and Exploration, 1981,* Article 11. https://dergi.mta.gov.tr

Larco Hoyle, R. (2001). *Los Mochicas, tomo II: Museo Arqueologíco Rafael Larco Herrera* (p. 350). Pueblo Libre.

Noble, D. C., & Vidal C., C. E. (1990). Association of Silver with Mercury, Arsenic, Antimony, and Carbonaceous Material at the Huancavelica District, Peru. *Economic Geology, 85,* 1645-1650. https://doi.org/10.2113/gsecongeo.85.7.1645

Noble, D. C., & Vidal, C. E. (1994). Gold in Perú: Society of Economic Geologists. *SEG Discovery, No. 17,* 1-13. https://doi.org/10.5382/segnews.1994-17.fea

Olaechea, T. (1901). Apuntes sobre el Castillo y fundición de Curamba. *Anales de Ingenieros de Construcción Civil de Minas e Industria del Perú, 6,* 1-21.

Petersen, G. (1970/2010). Mining and Metallurgy in Ancient Perú (p. 90). Trans. by Brooks, W.E., 2010, of Minería y Metalurgia en el Antiguo Perú, Arqueologicas 12, Museo Nacional de Antropología y Arqueología, Pueblo Libre, Lima. Geological Society of America Special Paper 467.

Rivero y Ustariz, M. E. (1857). Exploitación del guano en tiempo prehistórico. *Colección de Memorias Científicas: Agrícolas e Industriales, Lima, 1,* 159.

Romaña, E. (1908). *Una inspección de los yacimientos de estaño de Bolivia y una exploración por el mismo metal en el Perú.* Litografía tip Carlos Fabbri.

Soto-Viruet, Y. (2018). *The Mineral Industry of Peru: U.S. Geological Survey 2017-2018 Minerals Yearbook.* https://pubs.usgs.gov/myb/vol3/2017-18/myb3-2017-18-peru.pdf

Thrush, P. W. (1968). *A Dictionary of Mining, Mineral, and Related Terms* (p. 1269). U.S. Bureau of Mines Special Publication, U.S. Department of the Interior.

Topkaya, Y. A. (1984). Recent Evaluation of the Sart Gold Deposit. In V. Kudryk, D. A. Corrigan, & W. W. Liang (Eds.), *Precious Metals, Mining, Extraction and Processing* (pp. 85-101) AIME.

Yates, R. G., Kent, D. F., & Concha, J. F. (1955). *Geology of the Huancavelica Quicksilver District, Peru* (p. 45). U.S. Geological Survey Bulletin 975-A.