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The Emergence of Complex Silver Metallurgy in the Americas: A Case Study from the Lake Titicaca Basin of Southern Peru

This paper discusses the emergence of silver metallurgy some two millennia ago in the south central Andes. It is argued that the availability of multiple abundant resources and a high population density were instrumental in the development of this complex technology. The potential for such resource-rich environments to stimulate and sustain innovation is briefly discussed, particularly for prestige goods in societies engaged in socially competitive networks. The Puno Bay area of Lake Titicaca and its hinterland is shown to be one such resource-rich region, which may have contributed to its role in developing a complex and labor-intensive silver metallurgy as part of a larger mining-metallurgical landscape.

Introduction

This paper discusses the earliest known evidence for silver production in the Americas (Schultze, 2008, Schultze et al., 2009). High temperature metallurgy is among the more complicated inventions of the preindustrial world, with silver metallurgy the most complex one. In the Old World, it has been debated whether such technologies occurred as an invention in a single location and diffused outward to the rest of the ancient world (Roberts et al. 2009), or if instead the technology was invented independently in multiple centers (Radivojević et al. 2010). Data from South America bolster the idea of multiple, independent centers for the invention of extractive metallurgy. Here, in the absence of contact with the Old World, silver ore reduction technologies developed independently, likely in the Lake Titicaca Basin of the South-Central Andes. The invention of silver cupellation in the Americas is clear instance of the parallel evolution of a complex technology in the Old and New Worlds, in the absence of direct or indirect contact.

The Andean mountain chain is a rich source of gold, silver, copper, lead, tin, and mercury (cinnabar), forming numerous significant mining districts (Cooke et al., 2007, Tschudi and Ross, 1865, Ramírez, 1994, Berthelot, 1986) and providing ample opportunity for early metallurgy (Lechtman 1976). There is evidence for high temperature silver refining leading up to cupellation in the Lake Titicaca basin of Southern Peru beginning as early as 40 BC to AD 120. Unlike simple reduction of pure or near-pure silver ore, cupellation is a complex, multi-stage process that makes use of lead as a silver collector. This process involves separate reduction and oxidation steps, requiring sustained temperatures as high as 1100 °C and specialized furnaces and ceramics (Cohen 2008; Rehren 2011).

Figure 1. Project Location, Lake Titicaca Basin of Peru and Bolivia

The region in which this technology emerged can be studied to identify the sufficient and necessary factors for the invention/innovation of the prestige good metallurgical industry. For these purposes, the following distinction is made between invention and innovation (see also Roberts and Radivojević 2015),

> "... *invention* refers to the creation of novelty prior to substantial testing to determine its performance characteristics. *Innovation* refers to the broader process of assessing the performance utility of an invention or introduction prior to its broad adoption in the material repertoire of a culture group. In practice, these two processes are often overlapping and iterative" (Fitzhugh and Tresler 2009:218, note 1).

Successful complex metallurgy is unlikely to have been 'invented' in a single moment of time, because it makes use of many antecedent technologies, e.g. precise control of firing temperatures and furnace atmospheres that would have developed through ceramic firing and an in-depth understanding of the properties of several minerals, that would have been acquired through stoneworking and adding temper to ceramics. The 'innovation' discussed here is that of several existing techniques that were modified and employed to a novel purpose, specifically, the extraction and purification of silver metal from ore minerals.

But what drove these developments? Colonial period accounts make a strong case for the existence of pure or near pure metals in placer deposits (gold) and veins (silver) as a relatively common feature in the Andes (Craig and West 1994). This was an area of great abundance of human and natural resources. Spaniards encountered a massive command economy, with the Inca as supreme ruler able to direct large scale labor projects at will (Cobo 1653a [2005]). The Inca created make-work projects so that each person was certain to contribute labor to the state (Guaman Poma 1613 [2006]). However, state tribute was only a portion of the labor time of any given subject, which was also available for work on the farms and industries belonging to family-based corporate groups, called *ayllus* (Stanish 1992).

As such, the scarcity that would drive people to find ways to squeeze additional pure metal from stones was simply not present in this environment. And unlike the Old World, there was no direct economic incentive to do so. In the Americas, precious metals were not monetized prior to Spanish contact. Silver, gold, and copper metals played an important role in the prestige economy, but were only one among several high status ornamental and display goods, including finely woven cloth and exotic goods from the Amazon Rainforest and the Pacific Ocean.

Scarcity, abundance, innovation, and risk

So why devote time, intellect, and labor toward this specialized form of production? Human Behavioral Ecology (HBE) has created a framework for exploring decision making under conditions of scarcity (e.g. Morgan and Bettinger, 2012, Winterhalder and Goland, 1997) which, if accurate, must also be predictive (or retrodictive) of human behavior in contexts of plenty. There is a large body of literature examining strategies of risk and variability among foraging populations that seeks to model and understand the choices these groups – or individuals within these groups – may make to ensure survival and well-being. In the Andes, Craig (2005:473) has used behavioral ecology models to explore the implications for mitigating risk in the face of population pressure through territoriality and changes in subsistence modes in the development of his models of emergent social inequality and leadership in the Late and Terminal Archaic (ca. 4000 to 1500 BC) of the Lake Titicaca region. In a related vein, Plourde explores the implications of a model of costly signaling and aggrandizers in the emergence of a prestige good economy during the Middle Formative Period (ca. 1300 –

500 BC; Plourde, 2009; Aldenderfer, 2005).

In this discussion, we refer specifically to the work of Winterhalder et al. (1999), and the figure reproduced here (Figure 2) that describes a relationship between risk sensitivity and reward. This curve was initially designed to explain the region in the lower left of the curve, where risk is encouraged because the organism literally has almost nothing to lose. Any incremental increase in material well-being justifies the risk and expenditure of energy. However, the Andean case directs our attention to the upper right portion of the curve. Here, abundance is so great that there effectively is no risk to innovation. In the Andes, there was abundant raw material and also abundant labor. The diversion of skilled labor toward innovation in metallurgy did not constitute strain on the economic system. Metalworkers were free to innovate in a context of extreme plenty.

Figure 2. “Functional relationship between resource outcome and value (fitness, utility). A general sigmoid function. The sigmoid function illustrates the basic logic of risk sensitivity. For the concave portion, in which marginal returns are decreasing, an organism will prefer a constant outcome (k) to equal probabilities of a variable outcome (k+c, k-c). For the convex portion of increasing marginal returns, it will do better with the variable outcome,” reproduced from Winterhalder et al. (1999, Figure 1).

Ecological conditions or changes resulting in surplus yields can also be responsible for increasing cooperation and socio-political complexity (Hayden, 1995). In a situation where natural resources or material conditions are generally abundant, the cost of participating in a regional political economy is so low that it is easily outweighed by even minor benefits. This is not a case of necessity being the mother of invention, but rather of abundance being the instigator of innovation.

The concept of abundance (Smith, 2012: 29) also transcends the concept of surplus as a basis for the accumulation of political power; surplus, like scarcity, still implies availability in contrast to expectations. Smith (2012) has argued that an inherent seeking of abundance was a likely factor contributing to the emergence of urban centers, which came to represent concentrated loci of production and consumption. In short, the proposition is that conditions of extreme material and social abundance can drive individual and collective decision-making to as large a degree as do conditions of scarcity.

However, it is not enough simply to have labor power and resources. There must additionally be an economic or social incentive. Both theoretical models and experimental studies have shown that adequate effective population densities and knowledge exchange networks are required to develop and maintain complex cultural and technological traits (Premo and Kuhn 2010; Premo and Scholnick 2011; Lewis and Laland 2012; Derex et al. 2013). The availability of resources and technical know-how alone will not be sufficient to propagate a new industry within the prestige economy. There must also be a social environment in which a sufficiently large network of peer polities serves as both competition and audience for the generation of novel products, such as metal and alloys. This *richness* of network connections (Peterson 2015) ensures that new technologies will be both propagated and adequately esteemed to perpetuate long-term continued social investment in their development. These networks connections both drive and facilitate new technologies for the creation of prestige goods (Peterson 2015).

As detailed below, a rich network was present among the peer polity groupings of the Andean coast and highlands. In the Early Intermediate and Formative periods, there were effectively complex chiefdoms and competing peer polities from Ecuador to Chile. Innovation, status display, and competition/warfare were drivers of social change in this period. This culminated in the Andes becoming one of a handful of regions that saw the development of autochthonous states. Therefore, resource abundance and richness in the context of a competitive peer audience are here argued to be driving factors for the development of South American metallurgy.

Early South American Metallurgy

As part of developing social complexity, the physical and symbolic properties of precious metal were valued within the context of a prestige economy and as items of display, beginning in the earliest periods of Andean social development. The earliest known hammered native gold artifacts were recovered from the Lake Titicaca Basin Lake Titicaca's Ilave drainage dated to cal. 2155 to 1936 BC (Aldenderfer et al., 2008). In the North Coast region of Peru, into Ecuador and Colombia, hammered native metal artifacts have been found as early as 2000-1000 BC (Burger and Gordon, 1998). Copper smelting developed during the 2nd and 1st millennia BC, leading to an explosion of metalworking innovation during the Moche period, ca. AD 100-800. Archaeological evidence for this early metallurgy is scarce, but by AD 600 the Moche had developed all of the major technologies of alloying, gilding and soldering that are known in the Andean repertoire apart from tin bronze (Jones, 2005). Lake core data and workshop debris from the site of Ancón on the central Peruvian coast indicates silver ore reduction had commenced by that time (Cooke et al., 2008, Lechtman, 1976).

Elemental analysis of silver artifacts from the Late Intermediate period Mantaro Valley in Peru identified small quantities (0.2% to 1.6%) of residual lead in the silver artifacts, comparable to that of Mediterranean examples of cupelled silver (Howe and Peterson 1994). In the Potosí region of Bolivia, lake core data and smelting finds suggest extraction of silver using lead from at least around AD 1100 (Abbott and Wolfe, 2003). Still earlier evidence for smelting comes from high altitude plains surrounding Lake Titicaca, where lake and ice core data with evidence for lead-silver smelting go back up to 2,000 years, and the earliest workshop debris is found associated with dates of circa AD 60 to AD 120 (Cooke et al., 2008, Schultze et al. 2009, Eichler et al. 2015). The workshop material and environs found at the site Huajje, located in Puno Bay, Peru forms the data of this case study, presented below.

Lake Titicaca Basin Culture History

The Lake Titicaca basin, located in the central-volcanic zone (~3° to 33° S), is a volcanically active steep slab plateau with large and rich metal (Cu, Ag, Au, Hg, Pb) and oil deposits (Kay et al., 2004). The lowest point in the Basin is the surface of the lake itself, which sits at approximately 3810 m.a.s.l. Due to high elevation and tropical latitudes, the general environmental conditions are cold, windy, and stark with pronounced wet-dry seasonality. Despite these extreme conditions, extensive archaeological work has shown that the region was a center of independent development of complex society and an attendant array of technological innovations.

Period	Dates	Cultural Developments

Archaic	c. 12,900 – 1500 BC	Hunter-gatherers
Lower Formative	c. 1500 – 800 BC	Sedentary agriculturalists
Middle Formative Tiwanaku I (Kalasasaya)	c. 800 – 200 BC	Ranked societies
Upper Formative Tiwanaku III (Qeya)	c. 200 BC – AD 400	Competitive peer polities
Middle Horizon Tiwanaku IV Tiwanaku V	c. AD 500 – 1100 c. AD 500 – 800 c. AD 800 – 1100	Expansive state
Late Intermediate	c. AD 1100 – 1450	Warring chiefdoms
Late Horizon (Inca)	c. AD 1450 – 1532	Expansive empire

Table 1. The Lake Titicaca Basin Regional Chronological Sequence (after Levine 2012; Janusek 2008; Craig 2005; Albarracin-Jordan and Capriles 2011)

The Middle Formative Period (ca. 800 to 200 BC) in the northern basin was characterized by the emergence of rank and political hierarchy (Plourde 2006; Bandy 2001; Stanish 2003; Griffin and Stanish 2007). Large political centers signal the transition to the Upper Formative Period (ca. 200 BC to AD 400). This period includes the rise of competitive peer polities and highly ranked societies around Lake Titicaca (Stanish, 2003; Bandy and Hastorf 2007; Janusek 2004). In the 8th century AD, the first regional state of Tiwanaku arrived in two waves, first co-existing with local polities, and then, by the early 9th century AD, exerting a firm geo-political control over the region.

These developments were paralleled by a series of technological innovations. These included the domestication of camelids and potatoes, circa 4000 to 5000 BC (Craig 2005). Long-distance exchange and cultural contacts outside the basin are documented by circa 2000 to 1600 BC. Evidence for the domestication of the indigenous grain Chenopodium (*C.* quinoa; family *Amaranthaceae*) is associated with the Late Archaic to Early Formative transition prior to circa 1500 BC (Craig et al. 2010).

Concomitant with evidence of domestication and long-distance exchange is early evidence for metallurgical experimentation. This includes the earliest recovered precious metal artifacts in the Andes at the site Jiskairumoko, in Lake Titicaca's Ilave drainage (Aldenderfer et al., 2008). Hammered beads of native gold were associated with contexts radiocarbon dated to calibrated from 2155 to 1936 BC, prior to the settlement of permanent villages.

The Puno Bay data discussed below identified the site of Huajje as a silver ore reduction workshop from at least the Upper Formative period. The sequence begins in the very early first millennium AD and continues through the Spanish Colonial period, ca. AD 1600. The earliest dates associated with silver production are 1960 $\pm$40 BP (2-sigma cal. 40 BC to AD 120) and 1870 $\pm$40 BP (2-sigma cal. AD 60 to 240). Analysis of Middle Horizon bronzes from the site of Tiwanaku (circa 500 to 1100 AD) shows that innovation in alloying was underway at the capital of the Lake Titicaca Basin's first regional state (Lechtman, 2003; Couture and Sampek, 2003).

Because the Lake Titicaca Basin is located in a high plateau between the Cordilleras of the Andean mountain chain, it had access to resources and information from the Pacific Coast to the west and the Amazon Rainforest to the east (Stanish 2003). External links with distant, cosmopolitan cultures are implicated in the formation of early states in the Andes. In the Lake Titicaca Basin, the archaic state of Tiwanaku was a cosmopolitan center in its own right (Janusek and Blom 2006; Janusek 2005), but additionally had early contact with the culture of San Pedro de Atacama, Chile, which was a crossroads oasis with contacts reaching into Argentina (Torres-Rouff 2002; Torres and Conklin 1995). Similarly, the early state of Moche, on the north coast of Peru, was connected with an emerging polity at Piura that had links with more distant centers in Ecuador (Bawden 1999). Therefore, complex interactions with multiple emerging polities (i.e. *rich* network connections) are implicated in the evolution of social complexity in the Andes.

Puno Bay

The Puno Bay study area is about 100 square km surrounding the city of Puno, Peru along the shoreline of Lake Titicaca. The resources present in Puno Bay include andesite and basalt, clay, metal ores (silver, copper, and mercury), agricultural lands, lake resources, trade, and travel routes. Puno itself has significant economically valuable resources, which include the marsh plants (industrial textiles), birds, fish, and invertebrates of what now comprises the Titicaca National Preserve (est. 1978). In addition, large open pampa lands were available for farming, and hillside terracing for the intensification of agriculture date to the Middle Formative period.

The Puno survey identified a suite of sites devoted to different stages of silver production. In the following discussion, all ore and metalworking zones refer to Figure 3 and Schultze (2008).

Figure 3. Metal ore and workshop locations within the Puno Bay study area. Zone A=Santa Vela, B=Chincheros, C=Jallupata , D=Llallahuani, E=Huajje, F=Azoguine, G=Laykakota, H=San Antonio de Alba, I=Pumperia, J=Punanave , K=Molina, L=Pititquillia, M=Llushqha Llusqhani

The settlement pattern shows workshops cluster near raw material sources. Ore processing sites for silver (and possibly copper) production cluster down slope from hilltop mines. In the southwestern portion of Figure 3 is a cluster of sites centered around the silver source Laykakota (zone G), the location of the Colonial bonanza mine and town San Antonio de Alba, which was razed in 1668 when the mine was confiscated from the Salcedo brothers. This left behind no ruins, but there is abundant evidence of open pit mines, tailing piles, and ceramics from all periods of settlement, i.e. Formative, Middle Horizon, Late Intermediate and Late Horizon time periods. Other Inca period sites in the northern basin have well-constructed enclosed stone galleries (Schultze 2013), but at Laykakota mineral extraction appears to have been primarily through open pit mining (Schultze 2008).

The ridgeline refining and workshop site Punanave (area J) is downslope from the Laykakota mine. Punanave is a 17 hectare workshop site with broad artificial terraces in a location that catches the afternoon and nighttime winds off the lake. These terraces are littered with workshop debris that includes ceramic from all settled periods, andesite and chert tool fragments, crucible fragments encrusted with slag, and ore fragments. The size and form of the technical ceramics is consistent with those found at the site of Huajje.

Technical ceramic fragments, indicative of ore processing or slag re-processing (Martinón-Torres and Rehren 2014), were found at five locations across the project area. All of the sites with technical ceramics have a Formative component, while only three sites are represented in each of the later periods. Huajje (zone E), Punanave (zone G), and Jallupata (zone C) date to the Middle Horizon and Late Intermediate Period, while Late Horizon-associated ore processing sites include Huajje, Punanave, and Cerro Santa Vela (zone A). This reduction in site numbers over time implies a restriction of metal-producing activities to a smaller number of sites during the periods of more centralized political control.

Of particular interest is the site Huajje (zone E) on the shoreline across from Isla Esteves. It is a U-shaped monumental construction used as a metal ore processing workshop starting in the Formative period. This 2-stepped terrace mound has evidence for silver production, weaving textiles, ritual observance, and food consumption. A 2 m square excavation unit placed in the center front of the monument went down to 5.15m and recovered metallurgical debris in every level from 30 cm to 4.8 m. The earliest dates associated with silver productions range from AD 60 to AD 120 (Schultze et al., 2009). These dates correspond to the Upper Formative period, while the relative ceramic sequence indicates metalworking activities may already have taken place in the Middle Formative period.

The excavation recovered more than 3000 pieces of various debris types, including more than a thousand fragments of crucibles. The crucibles were plain wares of locally common clays. They have a simple open bowl shape with semi-circular cross section and are rather small, with only approximately 4 cm diameter. Many were encrusted with glassy slag. Additionally there were thick fragments of glassy slag, vesicular debris of likely furnace fragments, and two circular matte cakes, i.e. pieces of metal sulfide formed during smelting complex ores. A few pieces of ore and potential ores were also recovered. A detailed discussion of this material is given in Schultze et al. (2009), identifying the slag-filled small crucibles as the remains of a slag-reprocessing step that was probably aimed at recovering silver-rich material from smelting byproducts. Several pieces of the glassy lead silicate slag in the crucibles exhibit circular detachment scars within the pooled slag, indicating that a matte cake detached from the slag, most likely with a small button of lead-silver bullion underneath (Figure 4). In confirmation, we have two circular matte cakes whose shapes correspond to these circular detachments. Matte prills within the lead silicate slag contain a high percentage of remnant silver, of approximately 25% by weight in the sample examined (Figure 5). Lead metal prills associated with the matte were also found to contain similarly high levels of silver. It is reasonable to assume that the matte cake and lead-silver bullion piece that was taken away from this process would have been of similarly high silver content. Therefore, while re-processing the slag in small crucibles would have been a labor-intensive industry, it would also have had high yields.

Figure 4. Slag-encrusted technical ceramic/crucible from Huajje (4.3 to 4.4 m level) illustrating the anticipated by-products and elemental composition of slag reprocessing debris. The technical ceramic displaying adhered slag with a circular detachment scar. The detachment is evidence of a matte cake and nugget of bullion. A total of 1019 (3768 g) slag encrusted crucibles and 2 (19 g.) matte cakes were recovered in the Huajje assemblage.

Taking the evidence from different sites together, most steps of silver production are found in the study area, including mineral extraction from an ore deposit, primary smelting with lead, possibly in wind driven *huayrachina* furnaces (Van Buren and Mills 2005; Cohen et al. 2009; Rehren 2011), and reprocessing of rich slags. These would have been followed by the separation of silver from its lead collector in cupellation hearths. Fabrication of finished artifacts finally would have included hammering into sheet metal, and possibly alloying with gold and copper to create tumbaga. These final fabrication steps have not been documented in Puno Bay, but may have taken place elsewhere, possible near or within an administrative or ritual center of this mining-metallurgical landscape.

Figure 5. Two artifacts from Huajje illustrating the appearance of silver-rich copper-lead sulfide matte in the collection. In the upper left corner is a matte cake (3.1 to 3.2 m level). The center close up shows a matte prill within lead-silicate slag (dark grey). The silver content of the prill is 25% by weight. Optical micrograph, plane-polarized reflected light. Width of prill c. 2 mm. Sample nr P5-129a.

Summary and Conclusions

The idea of multiple, independent centers for the invention of extractive metallurgy is bolstered by the new data from South America. In the absence of contact with the Old World, we find silver ore reduction technologies developing perhaps in the Lake Titicaca Basin of the South-Central Andes. Although the North Coast of Peru is also identifiable as an early area of metallurgical experimentation, no evidence for silver-lead cupellation has yet been found there. The technology spread south to Potosí in the Late Intermediate period.

The Huajje assemblage included silver and copper bearing ores, lead silicate slags, and copper-silver matte cakes, in which were embedded globules of pure lead-silver metal. These artifacts are thought to indicate the processing of silver-containing slag from *huayarachina* smelting to recover small but rich matte and metal prills, to increase the overall yield. The penultimate (cupellation) and ultimate steps (artifact production) of this process are not represented among the assemblage; the missing objects would have been silver-lead bullion, pure silver itself, and the by-product of cupellation, lead-oxide (commonly called litharge). The first two of these are likely to have been jealously guarded in all periods. Litharge is likely to have been recycled back into the smelters to provide a lead collector at the initial step of refining. An ethnographic example of this process from Bolivia, including its technological requirements at each stage, is documented by Cohen (2008; see also Cohen et al. 2009), although without the crucible melting stage. Notably, the latter dominates the evidence at Huajje.

These finds demonstrate that significant labor-time and technological skill were invested toward extraction of metal from silver-bearing ores beginning in the earliest periods of political complexity. It remains an open question as to why these resources were expended in such a manner, given that Colonial period accounts make a strong case for the existence of pure or near pure metals in placer deposits (gold) and veins (silver) as a relatively common feature in the Andes; therefore, there does not seem to have been a lack of rich silver ore. Since the mechanical properties of cupelled silver differ little from those of native silver, a technological explanation for the invention / innovation of silver cupellation does not readily come to mind. Perhaps instead ideological or usufructuary considerations were at play. Mountain deities, called *apus*, were revered in Andean culture (Ramírez, 1994:95, Shimada, 1994). Therefore, a preference to protect these prominent physical landmarks by maximizing silver recovery from any ore removed is a possibility.

Access to primary sources may have been restricted to elite groups. In such a case, reprocessing would have allowed lower status *ayllus* access to the prestige metal. Additionally, different segments of the population were likely involved in the different steps of silver production. Developing a more complex technology would enable wider participation in the process, contributing to social integration as well as reinforcing social stratification.

Beyond these speculations, some general conclusions can be reached regarding the conditions that promoted the development of this complex metallurgical technology in this time and place. In the Puno Bay region, the development of labor-intensive industries for the extraction and purification of silver metal took place in an environment of extreme abundance that encompassed physical, technological, and social dimensions. It would be difficult to overstate the wealth of the physical environment, in terms of mineral ores as well as in the staple resources available with which to generate surpluses to maintain a specialist labor force. The ores were very silver-rich which means the processing would produce a high yield. Mining and metallurgy were labor intensive but there was a high reward.

The social environment of the Middle and Upper Formative was one of peer polity competition, increasing stratification, and social inequality (Levine 2012; Stanish and Levine 2011). Mechanisms within the political economy supporting these developments included an elaborate ritual complex and the investment of labor in intensive production as a marker of status and value. The prestige economy valued labor-intensive craft specialization across many industries, and silver metallurgy with its multiple steps lends itself perfectly for this. The connection between metal ore reduction and further processing and communal ritual appears in the settlement pattern data from Puno Bay, where the early experiments with ore processing co-occur with ritual and corporate architecture (Schultze 2013). Significantly, beyond the bay, there was a much larger social environment of peer-polity interactions with other civilizations of incipient and evolving complexity. These extra-territorial influences most likely played a critical role in expanding the available size of social groups, rates of innovation and the size of social bodies of knowledge (Plourde 2009).

This paper argues that for a prestige / status / largely non-utilitarian industry and product such as silver metal to have value there must be a sufficiently large network of other people and competing social groups to confer value upon it. Cultures exist in a network of social relationships with other groups, some friendly, some not (e.g. Flannery

1968, Orser Jr., 2005). This richness of network connections both drives and facilitates new technologies for the creation of prestige goods (Peterson 2015; Derex et al. 2013). Demand for prestige goods is driven by both inter-group competition (Fitzhugh and Trusler, 2009) and the need for long-distance communication of relationships through symbolism embodied in rare but durable objects (Mizoguchi, 2013; Demarrais et al. 1996).

Silver metal, through its embedded labor, inherent complex technology and superior durability is a prime example of a prestige material. The combination of resource-abundance, both geological and biological, in Puno Bay and the resulting population density in a competitive social environment provided the fertile ground in which early experimentation with rich ores and metals would have led to the development of complex technologies and the production of prestige goods such as silver. This complexity sets it apart from the earlier metallurgy of copper and gold, and offers unique opportunities to absorb labor and at the same time bind wider parts of society into its production, pleasing the gods and supporting the elite in their inter-societal peer competition. The beauty and durability of silver are only the outwardly manifestations of these inherent values.

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