Gilded Gold: Procurement and Production of Gold in the Ancient Mediterranean
A Case Study within the Brandeis Classical Studies Research Collection

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Spring 2017

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Acknowledgements

All that is gold does not glitter
Not all those who wander are lost;
The old that is strong does not wither,
Deep roots are not reached by the frost.¹

Thank you to Professor Ann Olga Koloski-Ostrow (AOKO) for all of her help, for being not only the best thesis advisor I could have asked for, but for all of her support over the course of my undergraduate career. From the first Classical Studies course I took at Brandeis University until now, four years and at least fifty pages later, I owe a great deal to her.

Thank you to Professor Andrew Koh for his help and support in being the one to make sure that I would be able to conduct the x-ray fluorescence analysis of the artifacts myself as well as for all of the support he has offered me during my undergraduate career. This thesis would not exist without the passion found in his archaeological chemistry courses.

Thank you to the Brandeis Classical Studies Department for the use of the CLARC, the PXRF, the Digital Humanities Lab and Anna Krohn, and four years of adventure.

Last but not at all least, thank you to my parents, for everything. Your support of me, my education, and my passion means more than can be put into words.

Introduction (methodology)

Pliny the Elder devotes a significant section of his *Natural History* to gold, citing that the marvelous metal is harvested not only by human hands, but also by the ants of India and the Griffins of Scythia\(^2\). Beyond this distinguished description of its procurement, gold is regarded as one of the first metals utilized by human civilization. This is a large deal in part due to gold occurring naturally in greater and more widely dispersed quantities and qualities than any other metal. And nowhere is this diversity of gold better illustrated than in the ancient Mediterranean.

This thesis explores ancient Mediterranean gold through a two-fold methodology: construction of a chaîne opératoire (procurement, production, use, deposition) paired with x-ray fluorescence analysis on the five gold artifacts located within the CLARC\(^3\). Through the former research aspect, the intent is to garner information about the different gold procurement sources (both geologically and geographically), metallurgical and manufacturing processes, and the different types of gold alloys. The latter element of this research will then be to evaluate the XRF\(^4\) results of the five gold artifacts for the purpose of determining their provenience.

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Technically both are true, there is a phenomenon in which Indian ants draw gold to the surface, and the mines of Scythia are rife with dinosaur bones which the miners thought to be Griffins

\(^3\) Brandeis Classical Artifact Research Collection (CLARC)

\(^4\) X-Ray Fluorescence Analysis (XRF)
Chapter 1: Chaîne opératoire

PROCUREMENT
Mining Processes

The process of gold procurement in the ancient Mediterranean consisted of the exploitation of native gold – gold in its free, elemental state found in two disparate forms as alluvial gold and reef gold\(^5\). Alluvial gold (also referred to as placer gold) deposits are formed through the weathering and disintegration of mineral-bearing rocks and veins and can be quantified as five separate types: eluvial (“hillside occurrences”), river and stream placers, river terrace (“bench deposits”), maritime placers, and buried placers (“deep leads”). This placer gold is resultantly found aboveground and in rivers and contains a comparatively smaller percentage of silver than reef gold\(^6\).

Reef gold has a comparatively larger percentage of silver than reef gold and is entirely found deeper within the ground (usually below 1000 feet down). Occurring as a native metal embedded within a soil matrix such as that of quartz, reef gold is the parent ore body of the aforementioned alluvial gold\(^7\). Hence, all gold is initially reef gold and only with specific environmental conditions does reef gold become alluvial gold in one of its many forms. In this way all reef gold is technically a “primary deposit” while alluvial gold is technically a “secondary deposit”\(^8\).

Just as many types of native gold in antiquity existed, there were equally many ways in which to procure the lustrous and illustrious substance. Alluvial gold – depending on its location – could be panned from sand and rivers (“placer mining”) or dug from short horizontal shafts.

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\(^7\) Healy, *Mining and Metallurgy*, 34.
\(^8\) Guerra, Maria F., Calligaro, Thomas. “Gold traces to trace gold” *Journal of Archaeological Science* Page 1199. ELSEVIER. 2004.
(“opencast mining”). Reef gold, however, could only be found by “underground mining” with deep, networks of horizontal and vertical shafts. Pliny the Elder whose work in Hispania Tarraconensis as a fiscal procurer\(^9\) allowed him insight and firsthand descriptions of the gold mining operations there breaks down potential gold-acquisition into a tripartite system.

The first procurement element of Pliny’s description is that of “gold dust” found in running streams and acquired through panning and washing. The second mode of gold acquisition is through the sinking of short horizontal shafts (essentially opencast mining). And the third process by which gold can be obtained is – by far the more arduous, but most common – through deep underground mining\(^{10}\). This methodology lines up closely with that other ancient sources including Strabo and Vitruvius.

Temporally alluvial sources were obtained first\(^{11}\) – originally by walking over the land and near bodies of eroding water and later purposefully by means of panning and prospecting and eventually opencast mining. When alluvial and inherently over-ground sources became scarcer and demand increased there was a push for underground mining and this focus on reef gold would later become the most common form of gold procurement.

Underground mining was a far more difficult and dangerous task; Pliny likened the process to the labors of the Giants\(^{12}\). And indeed the task was considered immensely hazardous and the labor force – enumerated below – was provided accordingly. By the light of regionally viable torches or oil lamps workers cut shafts (holes first vertical then horizontal to form a tunnel-like structure) into the earth that would connect to galleries (where the gold would be


\(^{10}\) Whalley, *Pliny the Elder, Historia Naturalis*, Book XXXIII Chapter 21.

\(^{11}\) Healy, *Mining and Metallurgy*, 74.

mined; larger than shafts). Ventilation and flooding were both issues the deeper – and closer to the water table – the workers went. Additional supports - either pillars of uncut earth or human constructed wooden pillars – were required to keep shafts and galleries from collapsing.

**Labor/Organization**

The organization systems and labor forces employed in mines differed in many minute ways, but a general structural trend tends to arise. For the most part mines are officially controlled by the state or governmental structure under which they geographically and politically exist. During the Classical period, the Roman state looked to ensure that a maximum yield of precious metal deposits was produced monitoring gold and silver mine production carefully. In newly won territories this state involvement sometimes manifested as military involvement with the actual mining process. Such is exemplified by the Roman military involvement in Britain’s lead and gold mines during their initial conquest. The participation of the military to this extent was, however, uncommon for most mines. A more common organizational structure was the leasing out of mines to private individuals who ran and provided the labor force.

Although private individuals owned and operated the mines of antiquity, rarely did free individuals do the work. The primary labor force of a mine consisted of slaves and criminals – or less often, conscripted local populations treated as such – and a small number of specialist individuals with the requisite knowledge to operate the mine. Diodorus Siculus writes of such organizations and labor forces in the gold mines on the frontiers of Egypt:

> “Those who oversee the work in the mines extract the gold by means of a multitude of workers, for the kings of Egypt gather up and hand over for gold-mining men who have

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14 Craddock, “Mining and Metallurgy,” 100.
15 Craddock, “Mining and Metallurgy,” 100.
been convicted of crimes, those taken prisoner in war, along with those who have fallen prey to unjust accusations and been thrown into prison through spite\textsuperscript{17},

and such seems to be the norm rather than an outlier, similarly supported by Pliny’s accounts of gold mining in Hispania.

\textit{Tools}

The basic tools employed by mine workers – hammers, (cold) chisels, different types of picks with varying blade thickness, mattocks, shovels, hoes, rakes, wedges, and fire (in the context of fire setting as well as illumination)\textsuperscript{18} – were all in use by the end of the first millennium. And the only great change in these tools was the replacing of stone, bone, antler, and bronze with those iron and steel\textsuperscript{19} in their composition.

\begin{itemize}
\item[\textsuperscript{17}] Humphrey, Oleson, and Sherwood, \textit{Greek and Roman technology}, 184.
\item[\textsuperscript{18}] Healy, \textit{Mining and Metallurgy}, 84.
\item[\textsuperscript{19}] Craddock, “Mining and Metallurgy,” 98.
\end{itemize}
A significant factor in regard to the procurement of gold in the ancient Mediterranean was the localities wherein said precious metal could be found. From the Tagus River in Spain to the Padus River in Italy, from the Hebrus River in Thracia to the Pactolus in Asia and the Ganges in India\textsuperscript{20} gold flowed in and around the river beds and earth of the Mediterranean. The general dispersal of this mineral wealth (specifically in regard to procurement sites) is pictured above.

\textsuperscript{20} Whalley, \textit{Pliny the Elder, Historia Naturalis}, Book XXXIII Chapter 21.
(Map 1: Ancient Mediterranean Gold Mining). The area from which gold was acquired can be broken up into smaller regional contexts - Britania, Hispania, Gallia, Italia, Egypt, Greece (and the Balkans), and Anatolia (and Cyprus) – as is outlined below.

Map 2: Britania

Britannia – depicted in the map above (Map 2: Britania) – is a significant if not largely-producing source of gold. While gold mining occurred from the very west of Britannia to the
furthest extent east - specifically in parts of Wales, Cornwall, and Scotland\(^\text{21}\) - gold less common than the other Mediterranean localities. Compared to the next region to be addressed – Hispania – the gold production of Britannia was a mere pittance. The best source of gold in the region was the gold mines at Dolaucothi\(^\text{22}\) located in central Wales (see Map 2: Britannia for location).

Map 3: Hispania

\[^{21}\text{Healy, Mining and Metallurgy, 52.}\]
\[^{22}\text{Craddock, “Mining and Metallurgy,” 95.}\]
A gold-rich region, Hispania provided a great quantity of many desirous metals, gold specifically. Pliny the Elder makes mention of Asturia, Gallæcia, and Lusitania as areas within Hispania capable of producing a great quantity of gold, Asturia most prominently\textsuperscript{23}. Pliny also mentions a large gold producing mine in the region Três Miñas\textsuperscript{24} which you can see on the above map under the title “Minas de Mouras”. The northwestern area of Lusitania was also hailed in antiquity as producing not merely gold, but a specific type of white gold\textsuperscript{25}. Beginning in the first century BC the main gold-producing parts of Hispania included the Esla valley, the Somedo mountains, Rio Duerna, Montefurado, Las Medulas and the Sil Valley, Puerto de Palo, Las Bacias, the Eo river, the Ocerro river, Coruña, Pontevedra, the Darro valley, the Genil valley, Turdetania, the river Ebros, the river Bilbilis, and of course Iberia\textsuperscript{26}. According to many ancient sources, among them Pliny and Strabo\textsuperscript{27}, Ilberia was the greatest source of gold and overall mineral wealth during the first millennium B.C.\textsuperscript{28}

\textsuperscript{23} Whalley, \textit{Pliny the Elder, Historia Naturalis}, Book XXXIII Chapter 21.
\textsuperscript{24} Craddock, “Mining and Metallurgy,” 104.
\textsuperscript{25} Humphrey, Oleson, and Sherwood, \textit{Greek and Roman technology}, 191.
\textsuperscript{26} Healy, \textit{Mining and Metallurgy}, 48.
\textsuperscript{27} Healy, \textit{Mining and Metallurgy}, 48.
\textsuperscript{28} Humphrey, Oleson, and Sherwood, \textit{Greek and Roman technology}, 185.
Map 4: Gallia

Nearer Italy and almost as abundant in gold and other precious metals as Hispania is the region of Gallia or Gaul (see Map 4: Gallia). The region, again in a fashion similarly to that of Hispania, was active from the first millennium BC onward\(^{29}\), and Diodorus Siculus spoke to the great quantity and quality of alluvial gold found in Gallic rivers\(^{30}\). Gallic gold was predominantly

\(^{29}\) Craddock, “Mining and Metallurgy,” 94.
\(^{30}\) Humphrey, Oleson, and Sherwood, *Greek and Roman technology*, 191.
obtained from the rivers rising in the Pyrenees, the Rhine river, the territory of Tarbelli (Basses Pyrénées), Haute Garonne, and the Tectosages in the Cévennes\textsuperscript{31}.

Map 5: Italia

Italia, inhabited by the Romans who frequently acquired gold from Gallia, Hispania, Britannia, and other Mediterranean sources was itself relatively poor in regard to mineral

\textsuperscript{31}Healy, \textit{Mining and Metallurgy}, 48.
resources. Along with a number of smaller mines (see Map 5: Italia), the chief sources of gold in the region during antiquity included ancient Victimulae and the Colline Metallifere mines (ancient Massa Metallorum, modern Tuscany). Additionally the Po river and the Alps provided smaller amounts of gold during antiquity, the latter further exploited during later medieval periods.

Map 6: Egypt

Across the sea from Italia, Gallia, and Hispania was Africa and Egypt (see Map 6: Egypt) another area containing great sums of gold and transported and traded both along and across the seas. Diodorus Siculus wrote extensively of the mineral wealth – gold specifically – in the

32 Healy, Mining and Metallurgy, 48.
33 Healy, Mining and Metallurgy, 49.
34 Craddock, “Mining and Metallurgy,” 94.
35 Healy, Mining and Metallurgy, 49.
36 Craddock, “Mining and Metallurgy,” 94.
frontiers of Egypt which possessed many widespread gold mines\textsuperscript{37}. Even the deserts of Egypt contained gold, the mines in the eastern region being a major source of gold from Pharaonic time onward as is demonstrated in the writings of Agatharchides and confirmed by archaeological findings therein\textsuperscript{38}.

Map 7: Greece and the Balkans

If we move eastward, beyond Italy, we come to the regions of Greece and the Balkans (see Map 7: Greece and the Balkans). Gold was comparatively rare within Greece prior to the

\textsuperscript{37} Humphrey, Oleson, and Sherwood, \textit{Greek and Roman technology}, 184.

\textsuperscript{38} Craddock, “Mining and Metallurgy,” 94.
exploitation of Macedonian mines by Philip II although a number of the islands had reef depositions. Conversely, the Balkans supplied much of the gold used within the Roman and Byzantine Empires. The area of Dalmatia yielded a great deal of gold in Pliny’s account and Illyria at Urbas within Dalmatia provided the majority of this gold. The Island of Sifnos was similarly famed for its gold production – to the extent that a treasury building was constructed at Delphi by the inhabitants of Sifnos to contain the gold they offered to Apollo; Sifnos produced gold primarily during the sixth century BC before declining in prominence. Other Greece-Balkan gold sources included Macedonia-Thrace specifically the mines at Dysoron and Mt Pangaeus, the gold mines of Thassos, the mines of Asyla and Scapte Hyle, the alluvial deposits found in the Hebrus River, and the mines at Madenokhorio on both sides of Mt Stratoniki.

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40 Humphrey, Oleson, and Sherwood, *Greek and Roman technology*, 182.
42 Craddock, “Mining and Metallurgy,” 95.
43 Humphrey, Oleson, and Sherwood, *Greek and Roman technology*, 182.
45 Healy, *Mining and Metallurgy*, 47.
Map 8: Cyprus & Anatolia

In the furthest eastern extent of this consideration of Mediterranean gold procurement sites we find the region of Anatolia - in this context in conjunction with the island of Cyprus (see Map 8: Cyprus & Anatolia). Anatolia was an immensely prominent metal source in the beginning of the first millennium BC with a major alluvial gold strike in the immediate vicinity of Sardis within the Pactolus River. This region near Sardis was the source of the famed Lydian gold used for the production of the first gold coinage. Additionally the earliest form of electrum

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46 Craddock, “Mining and Metallurgy,” 95.
“coins,” pebbles more than anything else, were found in this region. Aristotle also recorded rich mines located at the Syspiritis near Caballa (modern day Armenia) and at Stageira.
TRANSPORTATION

Transportation Routes Utilized in the Coveyance of Ancient Mediterranean Gold

Map 9: Gold Trade Routes

The transportation of gold occurred in a fashion similar to that of other goods and commodities within the ancient World. Over-land trade routes were the primary source of this conveyance of unprocessed gold (see Map 9: Gold Trade Routes). Of course, these GIS renderings can provide only tenuous static understanding of the trade routes at any given time in the ancient Mediterranean. Gold routes were frequently formed, shifted, and cut off by means of a variety of economical, ecological, and political factors, take for instance the cutting off of
Siberian gold routes entirely in the middle of the third century BC as well as the fact that the
gold procured from Hispania went – until 202 BC – through Carthage\textsuperscript{50}.

In certain circumstances, however, rivers were utilized - such as in the case of the
Lydians in the region of Mt Tmolus who transported their metals along the Pactolus and Hermus
rivers\textsuperscript{51}. This exploitation of water body transportation was separate from the aforementioned
procurement of gold from certain rivers and streams.

While much of the information regarding trade routes, roads, and the passage of ancient
Mediterranean gold has been parsed from literary and archaeological records, it is by means of
the below-enumerated x-ray fluorescence analysis and related methodologies which allow for the
tracing of gold back to its source - by means of an object’s elemental composition – that now
provides the most useful data in regard to how gold came to be conveyed.

\textsuperscript{50} Healy, Mining and Metallurgy, 47.
\textsuperscript{51} Healy, Mining and Metallurgy, 47.
METALLURGY

Metallurgy in the ancient Mediterranean was predicated upon the native metals gold, silver, and copper. This metallurgical importance was primarily due to their needing no preparatory treatment when found in said native form – especially gold. One of the major technological advancements in the Classical period of antiquity, however, was the introduction of gold refining – said development due in part to Lydians for the introduction of gold coinage.52

The general process of gold refinement – at the ore-stage of development rather than working of the native element – requires four fundamentals: gold ore (made ready for smelting), fuel (wood or charcoal), a furnace, and a crucible. In addition to this basic refining process two types of reduction methods are used to obtain pure gold, the first being furnace methods (smelting and cupellation) and the second being wet processes (specifically amalgamation).54

Unlike mining, the smelting methods used in antiquity evolved in the eastern Mediterranean (around the 3rd millennia BC) and remained largely unchanged.55 The process of smelting requires that the ore be broken up into small button-sized pieces (a procedure usually performed by hand with hammers, later anvils, and sometimes through use of water power) before being roasted in a smelting furnace which was typically cylindrical and made of clay (with chaff rather than charcoal as the fuel). This process usually took between six to ten hours, often performed at night. The preliminary purpose of any smelting operation on gold was to

52 Healy, Mining and Metallurgy, 68.
53 Healy, Mining and Metallurgy, 141.
54 Healy, Mining and Metallurgy, 152.
57 Healy, Mining and Metallurgy, 151.
eliminate the impurities primarily consisting of calcium carbonate, carbonic acid, copper, fluorspar, iron, silica, and zinc\textsuperscript{59}.

Cupellation (the other refining furnace method) is regarded as one of the oldest and best methods of separating “precious metals” from “base metals”\textsuperscript{60}. During the process of cupellation gold is alloyed with lead within - a specific type of crucible called – a cupel and the contents are oxidized by means of a strong air current being blown into the surface of the molten metal\textsuperscript{61}. A similar process called “parting” which makes use of acidic salts rather than lead was capable of separating silver from gold\textsuperscript{62}.

The wet-process refinement specific to gold is amalgamation wherein mercury is used to separate gold from other ores\textsuperscript{63}. This discovery of this process is credited to the Romans and a somewhat amalgamated account is provided by Pliny who describes the practice as combining mercury to silver-gold, forcing the compound through leather, and then applying heat\textsuperscript{64}. While the basic process does include the combining of mercury with such a native gold-silver substance before applying heat, there is no mention of leather in other ancient accounts.

An equally valuable skill utilized by goldsmiths was alloying which allowed said skilled individuals to fabricate gold objects with specific physical qualities. Alloying is the process through which a gold-worker could produce multiple gold alloys with differing physical and mechanical properties such as strength, hardness, ductility, and color\textsuperscript{65}. For example, through the process of alloying the hardness of gold can be improved (with the addition of copper and silver) and the color of the final alloy can be made more red (with copper) and more white (with silver).

\textsuperscript{59} Healy, Mining and Metallurgy, 152.
\textsuperscript{60} Humphrey, Oleson, and Sherwood, Greek and Roman technology, 209.
\textsuperscript{61} Guerra et. al, Gold Traces to gold, 1199.
\textsuperscript{62} Guerra, Maria F., Calligaro, Thomas. “Gold cultural heritage objects a review of studies of provenance and manufacturing technologies” Institute of Physics Publishing 1527. 2002.
\textsuperscript{63} Healy, Mining and Metallurgy, 152.
\textsuperscript{64} Humphrey, Oleson, and Sherwood, Greek and Roman technology, 210.
\textsuperscript{65} Guerra et. al, Gold Traces to gold, 1529.
As refining and alloying techniques and technologies were evolving, goldsmiths were developing other decorative techniques including soldering and gilding. Gold soldering is both the substance and way in which different pieces of gold can be joined together. The Romans had a specific gold solder called “chrysocolla” which Pliny claims to have been made from the combination of verdigris of Cyprian copper, the urine of a “youth who has not arrive at puberty”, and a portion of nitre, which was then pounded with a pestle of Cyprian copper in a Cyprian copper mortar. In addition to this “chrysocolla” solder malachite was utilized as a natural gold-solder and for gold impregnated with copper a solder of “gold and one-seventh part silver” in addition to the regular “chrysocolla” materials was formed.

Unlike the majority of the above processes that involve the combination or separation of gold from or with other metals, gilding is not mixed or parted from other substances but rather coated on top. There are a number of different types of gilding among them: water gilding, fire gilding, mercury gilding, and depletion gilding. The practice is essentially the same throughout wherein gold is applied to the surface of an object through heat or paste and was most commonly done for the purpose of making an object look finer than it really was.

In addition to these multitudinous chemical processes is the physical decoration of an object that could include the hammering, cutting, casting, chasing, engraving, stamping, gem setting, repoussé, stamping, filigree, granulation, niello, and inlaying methods. And once fully formed, further still, there were processes by which to test the purity and the final gold product. There were two primary ways in which this testing could be done: assaying by fire or by means

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66 Guerra et. al, Gold cultural heritage, 1528.
67 Whalley, Pliny the Elder, Historia Naturalis, Book XXXIII Chapter 29.
68 Humphrey, Oleson, and Sherwood, Greek and Roman technology, 225.
69 Guerra et. al, Gold cultural heritage, 1531.
of a touchstone. When heated and then returned to its initial temperature (by fire) purer gold will return to its original color. When a touchstone streaked pure gold it would look similar to a comparatively streaked pure sample.

**USAGE**

Ancient Mediterranean gold, once processed, came to be shaped for a great number of purposes. From the wondrous to the weird ancient gold fit itself to the purposes of coinage, human adornment, jewelry items, large-scale decoration, medicinal purposes, religious purposes, and a host of other such determinations. Coinage was the most far reaching of these utilizations.

**Coinage**

The earliest form of coins were made of electrum naturally found around Sardis in the sixth century BC. The Lydians were the first people to introduce and use gold coins – in conjunction with silver as a bi-metallic coinage system called “croeseid” and acquired from the Pactolus river and Mount Tmolus. The local standard of talents – predating coinage – first appears in the form of gold in the Homeric work the Iliad. In some places both before, during, and for a time after the introduction of coinage gold and white gold were also used in the production of currency rings. Throughout antiquity gold – in concurrence with silver and bronze – remained the three main metals utilized in the production of coinage with suspension only during times of political crisis.

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73 Humphrey, Oleson, and Sherwood, *Greek and Roman technology*, 228.
74 Humphrey, Oleson, and Sherwood, *Greek and Roman technology*, 486.
76 Guerra et. al, *Gold Traces to gold*, 1200.
77 Humphrey, Oleson, and Sherwood, *Greek and Roman technology*, 487.
**Human Adornment**

In antiquity many individuals – especially those with the wealth to do so – were adorned in gold. In the Homeric works there are descriptions of men wearing gold plaited in with their hair\(^{80}\). The Gauls similarly ornamented their hair with gold when engaged in combat according to Pliny’s sources\(^{81}\) and Diodorus Siculus writes of Gallic women ornamenting themselves in a similar fashion to their men\(^{82}\). Pliny also makes reference to the use of spun gold and golden weaving being used as fabric to create cloaks\(^{83}\), specifically that Attalic garments were given their name by King Attalus of Asia who invented the threading of gold into garments\(^{84}\). Other human adornments of gold continued from heads with hair plaited with gold to bodies wrapped in golden cloaks all the way to feet with gold as ornament for the sandal-ties of shoes\(^{85}\). Of course, there is one specific form of human adornment that fully endures to this day, that of jewelry.

**Jewelry**

The jewelry of antiquity was made chiefly of gold, silver, and that amalgamation of the two electrum\(^{86}\). The main jewelry items so composed included beads, belts, bracelets, brooches, buttons, chains, charms, earrings, finger-rings, fibulae, hair ornaments, pendants, and other less common articles\(^{87}\). Men would wear bracelets and rings\(^{88}\) – Roman senators wore golden rings provided at public expense\(^{89}\) - and women wore all forms of jewelry as aforementioned\(^{90}\). The gold in jewelry took the form of gold leaf or foil on gilded objects, gold and electrum articles of

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jewelry were decorated through filigree and granulation as well as wires and grains of gold, and acted as enamel. Of these enamels there were four types: champlévé, filigree (abovementioned), cloisonné, and dipped. Many examples of these items of jewelry survive today, including in the CLARC collection upon which this thesis is based.

**Large-scale Decoration**

Compared to the small-scaled fineness of jewelry, the realms of both architecture and interior decoration seem a distinct contrast. And yet both mediums applied gold to their own purposes with equal finesse. Ceilings, vaulted roofs, and even walls could be and in certain areas of opulence frequently were gilded or covered in gold. In Plutarch’s “Life of Pericles” the building projects of Pericles included the utilization of gold, goldsmiths, and goldworkers along with the more common place stone and stonecutters and stoneworkers. Furniture in similarly wealthy places also included goldwork in their structure and Pliny describes bedsteads made of gold and other such furnishings were plated with said metal. Sculptures of various makes and modes also used gold as accessories and statuary made of gold and ivory together had its own specific name “chryselephantine.”

**Medicinal**

The fields of medicine and surgery also made use of gold – as both a tool and a treatment. As a medical treatment gold was compounded with copper pyrites and salt then burnt into ash, the ash then being mixed with fat and applied as an ointment for a variety of ends. Surgical implements made of gold – while rare – were favored by doctors with high-class patients, and doctors hoping to curate a similar status often decorated their own implements with gold by

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91 Healy, *Mining and Metallurgy*, 244.
93 Humphrey, Oleson, and Sherwood, *Greek and Roman technology*, 264.
means of gilding, overlaying, inlaying, embossing, repousse, chasing, and stamping. Additionally, certain medicaments were stored solely in containers made of gold.

**Religious**

As might be anticipated, a final prominent fashion in which gold was fitted in the ancient Mediterranean was within a religious context. Votive offerings were frequently formed of gold as were parts of certain temples. According to Pliny gold was even employed in sacrificial offerings and it was said to be the greatest mark of honor for the given deity were an individual to gild the horns of a sacrificial animal.

**DEPOSITION**

Having procured, transported, processed, and used an artifact of gold, what is left but to dispose of it? Indeed, a great deal. Unlike many other types of artifacts that are made of less valuable and less recyclable materials, gold is, by its very nature both valuable and re-usable. While sometimes found in funerary contexts – buried with the dead or used for elements of the funeral process – gold is reused and recycled where many other substances come to an end. Pliny himself spoke to the value of gold when stating that gold alone was a substance found in nature that suffers no loss from the action of fire and “passes unscathed through conflagrations and the flames of the funeral pyre.” In this way gold was most useful in its ability to endure and be remelted and reshaped. Of course, this in itself will prove a problem for the next section of my thesis – the analysis of ancient Mediterranean gold artifacts by means of x-ray fluorescence analysis for the purpose of determining provenience.

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100 Whalley, *Pliny the Elder, Historia Naturalis*, Book XXXIII Chapter 12.
TYPES OF GOLD

As has been made clear by the above chaîne opératoire there are many different types of gold underneath the ancient Mediterranean umbrella. In the modern day there exist more than 5000 metal alloys. In the ancient world, however, metal alloys were limited to those of “white” gold, “green” gold, electrum, bronze, copper, bronze, arsenic, steel, brass, and pewter.102 A particular curiosity in regard to ancient gold is the way in which “gold” as a certainty was quantified. The modern notion of gold relies on the Law of Constant Composition wherein an element is defined with precise properties reinforced through modern scientific concepts while ancient metals coming from various sources with widely different properties could still be considered equally gold.103 In this way a light colored gold from one locality would be regarded as the intrinsic gold of that place instead of a different alloy with a naturally occurring high silver content.104 With such in mind this work seeks to determine and outline the different distinct typologies of gold: native gold, refined gold, white gold, electrum, and gold-copper.

Native Gold

Pliny himself describes native gold as a substance found in small clump and dust-like forms (alluvial deposits) and being immediately in a “state of perfection”. This inherent refinement is in direct contrast to that gold which must be refined from ore through firing.105 Certain non-metallic impurities – among them quartz and ferric hydroxide – are good indicators of pure gold in a processed object as said materials would be removed during the melting and heating processes other golds undergo.106 This “native” gold characteristically contains

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102 Healy, Mining and Metallurgy, 199.
105 Whalley, Pliny the Elder, Historia Naturalis, Book XXXIII Chapter 19.
106 Healy, Mining and Metallurgy, 217.
somewhere between 5 and 30 percent silver\textsuperscript{107}. Pliny quantifies native gold as containing silver in proportions ranging from a tenth to an eighth\textsuperscript{108}. In regard to an average elemental composition native gold contains 99 percent gold and silver with between 0 and 1 percent impurities (copper, iron, other minerals).

\textit{Refined (to pure gold)}

As aforementioned in the discussion of metallurgy, a number of processes existed by which gold from reef deposits could be refined to a “pure” gold. The basic refinement process took gold ores and parsed out their impurities leaving pure gold akin to that naturally found in alluvial deposits behind\textsuperscript{109}. The cupellation process was specifically applied to remove silver from gold and a lack of silver would be similarly indicative of this process. In this way gold devoid entirely or of specific impurities could be linked to being of this type.

\textit{White-Gold & Electrum}

The two main Mediterranean alloys comprised of silver and gold were known as white gold and electrum respectively; the two are frequently confused in both ancient and modern sources and as such misperceptions frequently arise. White-gold is a natural mixture obtained directly from the heat treatment of weathered auriferous ore (naturally found) while Electrum is an artificial alloy (purposefully produced) of gold and silver (often with the addition of copper)\textsuperscript{110}. Pliny specified that wherever the proportion of silver to gold is one-fifth that the ore is called electrum, meaning essentially that any gold containing 20 percent or more of silver

\textsuperscript{107} Craddock, “Mining and Metallurgy,” 106.
\textsuperscript{108} Healy, Mining and Metallurgy, 203.
\textsuperscript{109} Craddock, “Mining and Metallurgy,” 106.
\textsuperscript{110} Healy, Mining and Metallurgy, 201.
should be classed as electrum (rather than gold)\textsuperscript{111}. Isidorus defined electrum as a ratio of $3 : 4$ gold : silver while at Mytilene and Phocaea the ratio was $1 : 2$ gold : silver\textsuperscript{112}.

White-gold was, as is recorded by Pliny and confirmed by modern methods, a naturally occurring mixture of gold, silver, and small quantities of other metals (primarily copper)\textsuperscript{113}. White-gold with silver inclusions between 8 and 25 percent was characteristic of the Aegean\textsuperscript{114}. The substance was also characteristically found in the northwestern most part of Lusitania in Spain\textsuperscript{115} as well as Asia Minor around Sardis\textsuperscript{116}.

Electrum was produced through the alloying of “pure” gold with silver (and small quantities of copper)\textsuperscript{117}. This creation of electrum increased the hardness of the metal and was done partially for economic reasons (less expensive than pure gold) and partially due to the exhaustion of the white-gold supply\textsuperscript{118}. It is necessary to note that electrum was purposefully made to mimic both the appearance and advantage of natural white-gold\textsuperscript{119}.

\textit{Gold-Copper Combinations}

The other significant metal found naturally and purposefully alloyed with gold in significant quantities is that of copper. In this way, an amalgamation of copper and gold can be quite significant. “Corinthian bronze” was the term applied to an alloy of gold, silver, and copper distinct from the aforementioned ternary alloy electrum\textsuperscript{120}. When copper alone is mixed with gold the result becomes dull and difficult to work with, termed “aerosum” by the Romans\textsuperscript{121}.

Lastly and most significantly, due to the complex and difficult processes necessitated for the

\textsuperscript{111} Healy, \textit{Mining and Metallurgy}, 202.
\textsuperscript{112} Healy, \textit{Mining and Metallurgy}, 203.
\textsuperscript{113} Healy, \textit{Mining and Metallurgy}, 75.
\textsuperscript{114} Healy, \textit{Mining and Metallurgy}, 46.
\textsuperscript{115} Humphrey, Oleson, and Sherwood, \textit{Greek and Roman technology}, 191.
\textsuperscript{116} Humphrey, Oleson, and Sherwood, \textit{Greek and Roman technology}, 486.
\textsuperscript{117} Healy, \textit{Mining and Metallurgy}, 227-228.
\textsuperscript{118} Healy, \textit{Mining and Metallurgy}, 240.
\textsuperscript{119} Craddock, “Mining and Metallurgy,” 106.
\textsuperscript{120} Healy, \textit{Mining and Metallurgy}, 203.
\textsuperscript{121} Healy, \textit{Mining and Metallurgy}, 155.
separation of copper and silver from gold metal, any amalgamation of gold containing more than 99 percent “pure” gold or more than 5 percent copper belong to the last two millennia\textsuperscript{122}

\textsuperscript{122} Healy, \textit{Mining and Metallurgy}, 217.
Chapter 2: Modern Analytical Techniques (x-ray fluorescence)

**X-RAY FLUORESCENCE ANALYSIS**

*How XRF works*

X-ray fluorescence analysis relies on the x-rays emitted by the sample (or artifact) excited by x-ray tubes and radioactive sources or electron beams respectively\(^{123}\). What this means is that an XRF analyzer determines the elemental composition of an object by exciting the object with an x-ray source for the purpose of recording the x-ray fluorescence resultantly emitted by the object in response. A viable comparison is to imagine a bat trying to determine the identity of an insect. The bat emits a soundwave (the XRF x-ray source) which comes into contact with the insect (the artifact) which then bounces back (fluorescent x-ray emission) and can be comprehended by the bat (recorded). In this circumstance rather than a tempting mosquito we have alluring ancient gold artifacts with which to contend.

XRF technology is the “gold-standard” for accurate, nondestructive elemental analysis specifically with metal analysis applications\(^{124}\). This analytical precision and nondestructive nature requisite when dealing with items of a valuable nature. In this circumstance the analytical precision of the XRF allows for all major elements contained within ancient gold alloys – gold, silver, copper, and other impurities – to be determined\(^{125}\) and for the continued preservation of the CLARC artifacts – due to not damaging them for the purpose of scientific inquiry.

**Goal of this Thesis**

In antiquity individuals with the requisite experience could determine the proportion of gold, silver, and copper within a gold alloy by means of a single scrape along the surface with a

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\(^{123}\) Guerra et. al, *Gold cultural heritage*, 1528.


\(^{125}\) Guerra et. al, *Gold Traces to gold*, 1205.
touchstone or passing the object fire. In the modern day this skill has been lost and replaced with methods of scientific analysis. The aim of this thesis is to use the abovementioned chaîne opératoire and apply its elemental findings to the x-ray fluorescence analysis conducted on the five gold CLARC artifacts. In this way the elemental composition of the artifacts will provide insight into the most viable and significant areas of provenance – which in this context – including: alluvial gold versus reef gold, geographical source (Italia, Hispania, Gallia, Britannia, Greece/Balkans, Anatolia/Cyprus), metallurgical and manufacturing process, and post-production gold typology (gold, white-gold, electrum, or copper-gold)

**Personal Research - XRF Findings**

![XRF Findings](image)

Figure 7

---

Table 1

Artifact 540 within the CLARC collection is a gold-plated buckle with a single flower decorating the front side (see Figure 1, Figure 2). The XRF results for this piece determine that the base metal of which the buckle is made is an amalgamation of iron and copper (see Table 7) gilded with pure gold, with slight impurities of zinc. These zinc impurities indicate that the gold in question did not undergo the smelting process likely coming from an alluvial deposit. The lack of silver within the gold indicates that the process of cupellation was undergone. As the artifact is primarily copper and iron based with gold acting only as a very thin gild (likely although not definitively fire gilding), the diagnostic elements of this piece are minimal.
Table 3

Artifact 538 within the CLARC collection is an ovoid piece of gold foil inscribed with raised stylized vines with small holes around the edges (see Figure 3). The XRF results for this artifact indicate a large amount of gold, a small amount of copper, a slightly smaller amount of silver, and a trace amount of nickel (see Table 9). The quantity of copper being greater than that of silver within the gold is distinctive, and the lack of other impurities indicates that this ratio and combination is purposeful. One possible explanation for the gold to copper to silver ratio is that it may be an example of the copper-gold blend “corinthian bronze” or a similar alloy (which also indicates that the piece underwent alloying); the results show too that the copper to silver ratio is too great for the substance to be either the naturally occurring white-gold or man-made electrum. Unfortunately, while this distinguishing ratio is certainly compelling, and the metallurgical method is clear, it provides little basis for geographical context.
Artifact 515 within the CLARC collection is a portion of an ivory pin with a golden sheathed circular top (see Figure 4). The XRF results for the pin demonstrate a high portion of gold, a small portion of copper, and small traces of iron and nickel (see Table 10); additionally, the calcium composition detected through the second scan focused on the pin’s body indicates that the piece is made of ivory (see Table 11). The lack of silver in these results again speaks to the application of the cupellation process while the impurities of copper, iron, and nickel indicate
the lack of smelting. This does come through a refining process rather than an alluvial source as there is a lack of the tell-tale non-metallic pure gold impurities such as quartz and ferric hydroxide. While the XRF results did determine that the pin base is made of ivory, the gold element is not beneficial in the pinpointing of geographical context.

Figure 11

Table 5

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</table>

Artifact 539 within the CLARC collection is a golden pendant with a green emerald set at the bottom (see Figure 5). The XRF findings for this piece of gold jewelry were indicative of a
composition containing a large amount of gold, around 12.5 percent silver, and impurities of copper, nickel, and iron (see Table 12). This gold to silver ratio falls just below Pliny’s description of white-gold with 20 percent silver content but fits the parameters of the white-gold common within the Aegean with silver between 8 and 25 percent. While potentially tenuous, the possibility of tracing this gold to a geographical context is exciting and can be further explored through comparative analysis. Such analysis is one potential way in which this research can be further expanded – by means of comparing the samples and results from this study to those from other similar analyses and building a comprehensive knowledge base.

Figure 12
Table 6

Artifact 157 within the CLARC collection is a thin gold brooch decorated to depict a female head (see Figure 7). The XRF findings reveal a high gold quantity, a small silver quantity, a small copper quantity, a small iron quantity, and a very small quantity of nickel. All of these elements found in these amounts suggests that this is a form of native gold which underwent no cupellation or smelting processes and could potentially have been from an alluvial deposit. The exact manufacturing provides the possibility that the artifact was worked solely with physical methods such as hammering (to flatten) and engraving/stamping to emphasize the details and underwent little to no chemical process changes.
Conclusion and Considerations for Further Research

In summation, a piece of gold in the ancient Mediterranean underwent a multitude of processes in a viably linear narrative: from procurement to deposition, each step along the way left its mark upon the piece of gold. Due to these marks, by examining and analyzing gold artifacts, elements of their provenance – initial geological type, procurement process, geographical context, transportation, metallurgy, manufacturing, decoration, usage, and deposition – can be determined. With the addition of XRF analysis further details are revealed, including the exact elemental composition.

While the overall findings in regard to the CLARC gold artifact case study are more open ended than initially intended, they provide insight into further ways in which this methodology can provide the provenience information that many ancient artifacts sorely lack. Although these findings were not as geographically diagnostic as hoped, with comparative research – as this kind of elemental composition analysis has gained traction and been applied to many artifacts within the ancient Mediterranean context – still more provenance-related knowledge can be garnered for these, and many other, artifacts.

In regard to next steps, there are certainly worthwhile short and long term directions this research could go. The first step would be to a wider knowledge base. On a local level, there are numerous channels by which to acquire further ancient artifact XRF analyses. One highly viable avenue for this furthering of the research would be to access the results of the XRF analysis conducted on gold artifacts – including a funerary mask and collection of rings – recently conducted by ARCHEM through a Brandeis Collaborative study of select Cretan artifacts. A larger-scale step would be to interface with other small gold-artifact-containing-collections and archaeological digs to establish a database of XRF results and artifact provenance correlation. In
a best case scenario, with enough research, a comprehensive compositional base-line could be established for all ancient Mediterranean gold artifacts, solving the issue of provenance for an entire subset of metal artifacts.
Appendix A: Gold CLARC Artifacts

Figure 1

540 – Gold-plated buckle

Gold plated buckle with an embossed flower in the center approximately 0.9 cm high. The back of the belt buckle has a strip for slipping the other material through, and the front of the buckle over this strip is raised. On the opposite side the edge of the buckle is cut in a jutted triangular pattern. Parts of the gold plating are rubbing off, especially on the flower relief. The back of the buckle is not plated.

Length: 2.6 cm, Width, 2.6 cm, Height: 0.9 cm
Figure 3  
**538 – Gold Foil Fragment**

The ovoid piece of gold foil is inscribed with a raised stylized vine pattern. There are small holes at the narrow ends of the foil. The edges have begun to deteriorate.

Height: 2.5 cm, Width: 5.2 cm

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Figure 4  
**515 – Gilded pin head**

Head of an unknown object (perhaps a pin), made of wood or ivory, sheathed in gold leaf. The surface is cracked and flaking, leaving major gaps in the gold sheathing, the gilding having entirely disappeared from the final centimeter. At the rounded head of the handle, the gilding holds more completely, with the exception of a large bare area which is marred by a deep crack, another shallower crack marring the surface on the other side.

Length: 3.3 cm, Diameter: 0.4 cm, Diameter at head: 1.1 cm, Circumference 1.256 cm, Circumference at head: 3.454 cm
Gold pendant with a green stone set in the bottom. There are circular impressions lining the body of the pendant with a loop handle on the top end. The loop is relatively square, though this shape may be a distortion of a once-round ring. There appear to be several clearly layered sheets of gold-leaf wrapped around the stone.

Length: 5.9 cm, Width at bottom: 0.8 cm, Width at clasp: 0.6 cm, height at highest point: 1.1 cm, circumference: 2.512
Figure 7

Figure 8
Figure 9

157 – “Gold Brooch”
Late Roman, c. second to third century CE

Thin, delicate, gold brooch with the pin intact, but missing the clasp. The piece is round with small dots around the edge. A female head decorates the center with wrinkles in the gold around her. The face is simple with two pin-points for eyes, a tiny nose, and almost no mouth. The hair is short and not stylized. There is a chip of the piece, but it is unknown where it fits.

Currently on display in Goldfarb library

Gift of Mr. Richard R. Wagner, West Barnstable, MA, 1976

Diameter: 4.1 cm
Appendix B: XRF data

Artifact 540

![ARTAX - ELEMENT ANALYSIS](image)

Table 1

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Figure 7
Artifact 540b

**ARTAX - ELEMENT ANALYSIS**

Spectrum: SavannahGold1b
Method: 600µA-100S

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Table 2

Figure 8
ARTAX - ELEMENT ANALYSIS

Spectrum: SavannahGold2
Method: 600μA-100S

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Table 3

Figure 9
Artifact 515a

**ARTAX - ELEMENT ANALYSIS**

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Method: 600μA-100S

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Table 4

![Graph](image)

Figure 10
Artifact 515b

ARTAX - ELEMENT ANALYSIS

Spectrum: SavannahGold3b
Method: 600μA-100S

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Figure 11
ARTAX - ELEMENT ANALYSIS

Spectrum: SavannahGold4a
Method: 600μA-100S

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Table 6

Figure 12
Artifact 157

ARTAX - ELEMENT ANALYSIS

Spectrum: SavannahGold5
Method: 600µA-100S

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<td>Zn</td>
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Appendix C: GIS rendered Maps
(based on map of Mediterranean Mining Sites in John F. Healy’s Mining and Metallurgy in the Greek and Roman World)

Ancient Mediterranean Mining Locations

Map 1: Ancient Mediterranean Gold Mining
Map 2: Britannia
Map 3: Hispania
Map 4: Gallia
Map 5: Italia
Map 6: Egypt
Map 7: Greece and the Balkans
Map 8: Cyprus and Anatolia
Transportation Routes Utilized in the Coveyance of Ancient Mediterranean Gold

Map 9: Trade Routes
Bibliography


