# Chapter 18
# Preventing Art and Antiquities Crimes Using Forensic Geology

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**Abstract** Geological materials, such as gems, precious stones, precious metals, rare fossils, and archeological objects, are extremely attractive to organized crime because of their high economic value, small size, and non-traceability. Because of the traceability of bank transactions at international levels, criminal organizations are using precious means of exchange for traffic in arms and drugs, for money laundering, and for illegal trade. In addition to these crimes, precious geological materials are often falsified, forged, and imitated by methods that have reached such advanced techniques as to produce specimens almost perfectly identical to their natural counterparts, to the point that it is not easy to distinguish the differences.

This paper focuses on the main characteristics of valuable geological materials (gems, precious metals, and rare fossils), which are also of archeological interest, their falsification, and the techniques of forensic geology used for their study.

**Keywords** Geological materials · Gems · Fossils · Precious metal · Illegal trade · Forgery

## 18.1 Introduction

Precious geological materials are all those natural materials, such as precious stone and metals, gems, and rare fossils, that thanks to their rarity and beauty have reached a great economic value.

The characteristics of these materials have made them extremely attractive to organized crime due to their high monetary value, small size, and non-traceability. In fact, criminal organizations are using precious means of exchange for traffic in arms and drugs and for crimes that require a monetary transaction, with the aim of avoiding the traceability of bank transactions at national and international levels. Gems, as well as jewels, precious metals, and works of art, are used for money

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laundering by criminal associations as an alternative form of investment for illegal proceeds. This aspect has dramatically increased illegal trading and smuggling, which involves countries such as China, Russia, Afghanistan, and many tax havens. For example, over approximately 4 years (2008–2012), 1.5 tons of gold worth more than 26 million euros were smuggled into Italy (Capuano 2010; Di Maggio et al. 2013). In addition to these crimes, there are also those relating to the fraudulent falsification and imitation of precious geological materials.

## 18.2 Historical Overview of the Falsification of Precious Geological Materials

Already in ancient times, it was customary to falsify gems; the earliest evidence of changing the appearance of gemological material dates back to the Minoan era. During the ancient Roman period, Latin writers Pliny the Elder and Fedrus recount how some artisans were reported because they faked silver objects in the names of two of the most famous Grecian artists Praxiteles and Myron (Di Maggio and Barone 2017; Giacosa 2017).

One of the most famous episodes of fraud by falsification was reported by the Latin writer Vitruvius. He relates that Archimedes started to study hydrostatics because he was asked by his cousin King Hiero the Second to determine whether his crown was made of pure gold or an alloy with silver (Di Maggio and Barone 2017).

It seems that Archimedes, pondering how best to solve the king's problem, went to the public baths for his daily bath. Archimedes noticed that the more his body sank into the water, the more water ran out over the sides of the tub. He realized that he had found the solution to Hiero's problem; Archimedes had discovered the method for measuring the volume of an irregularly shaped object. Archimedes knew that gold was denser than silver, so a piece of gold weighing a certain amount would be smaller than a piece of silver weighing the same. Thus, the total volume of a gold plus silver crown would be greater than the volume of a pure gold crown. Archimedes found that the crown displaced more water than a lump of gold of equal weight. Thus, he concluded that the crown was not pure gold.

From the ancient Roman Empire until the Middle Ages, the art of falsification of precious objects developed increasingly, and it also became interested in objects of art and religious items, such as artifact and relics. In particular, the interest in Christian artifacts, both economic and religious, developed in parallel with the dissemination of Christianity in the Mediterranean basin, and although in the first centuries after Christ these objects consisted of relatively poor materials, they were considered of great value from the religious and liturgical point of view (Giacosa 2017). The allocation of this intrinsic value generated the wide development of trade in forged or falsified precious religious objects. Until the end of the Middle Ages, the falsification of precious objects had never been counteracted.

Only during the fourteenth century, in an effort to prevent and counteract the falsification of silver objects, did hallmarks on precious objects start to be used


**Fig. 18.1** Some of the most important hallmarks used in the Kingdom of Naples

(Fig. 18.1). Successively, the master silversmiths started to create their own hallmarks to prevent the selling of fake silver objects in their names (Giacosa 2017).

With respect to coins, since ancient times when money substituted for the barter system, many false gold and silver coins have been produced and issued into circulation. Regardless of the collection of old coins, falsification had already started in the Renaissance (with the birth of numismatic collecting); to complete coin collections with "missing pieces," fakes were artfully created (Giacosa 2017).

The first synthetic gems were produced in the mid-nineteenth century, and in the early years of the twentieth century, synthetic copies reached an acceptable quality.

Over the centuries, with the new knowledge of materials and the development of chemical and physical techniques, artificial alternatives based on lower-value materials have evolved as replacements for precious metals and gems.

## 18.3 Gems and Precious Stones

Gems are special minerals and, much more rarely, rocks that thanks to their beauty, hardness, and rarity have an extremely high monetary value. In general, a precious stone is defined as a mineral from which a gem can be extracted; the cut and finished gem itself is then considered as a mineral often used in jewelry. There are also gems of organic origin such as amber, coral, pearls, and ivory.

Since Neolithic times, mankind has vested particular interest in precious stones, using them not only as valuable ornaments but also as symbols evoking magical and spiritual virtues (Di Maggio et al. 2013). Unfortunately, gems and precious stones have not attracted people only for their beauty; because of their rarity and high economic value, the practice has evolved of resorting to various kinds of falsification.

### *18.3.1 Methods of Falsification*

Falsification of gems occurs mainly by three methods: exaltation, synthesis, and replacement (Di Maggio and Barone 2017).

The exaltation of gems is a practice that allows for the embellishment of precious stones, enhancing the features already present or hiding defects that are commercially underappreciated to artificially transform a poor-quality gem into a more prized specimen. Exaltation has been already in use for several centuries, and it is mostly performed to improve or change the color of the gems. Color is a characteristic that enables the identification of a gemstone and the estimation of its value, although gems that belong to the same mineralogical species may have completely different colors. However, color is one of the most easily forged features. Today, there are many treatments for enhancing the color, using techniques of irradiation or heat treatment (Fig. 18.2).

Other types of exaltation involve procedures for hiding clearly visible fractures or cracks. In fact, gems have distinctive signs, which may be superficial (called surface signs) or internal (known as inclusions), and are formed during the mineral crystallization process. The purity of a gemstone relates to its degree of internal clarity and to the nature, number, arrangement pattern, and size of the solid and liquid inclusions. Usually, the greater the purity of a gem, the greater is its value, especially for diamonds.

In general, the various kinds of exaltation are easily recognizable with low-power microscopy, even though the techniques are in continuous evolution.

Synthesis consists of artificially reproducing gems, with specimens having the same chemical, physical, and optical properties as the corresponding natural gems. There are different synthesis processes; however, the most common one consists of melting a material with a composition equal to that of the imitated mineral and adding metal oxides to obtain the desired coloring. The first synthetic specimens were already being produced in the middle of the nineteenth century. The synthetic stones are quite recognizable under the microscope as they exhibit typical curvilinear striae of growth and sometimes gas bubbles (Fig. 18.3). In recent times, however, the methods of synthesis have achieved advanced techniques to obtain products almost perfectly identical to their natural corresponding minerals, to the point that the differences are not easily distinguished. In these cases, identifying the products of synthesis often requires the use of very advanced and expensive instrumentation.

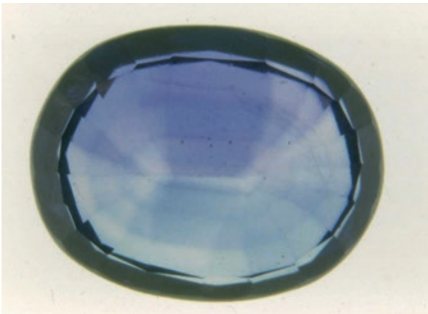

**Fig. 18.2** Sapphire exalted by heat treatment with the diffusion of foreign chemical elements; the color is not naturally homogeneous and is concentrated at the edges of the gems. Courtesy of the Gemological Institute CISGEM (Centro Informazioni e Servizi Gemmologici), www.cisgem.com

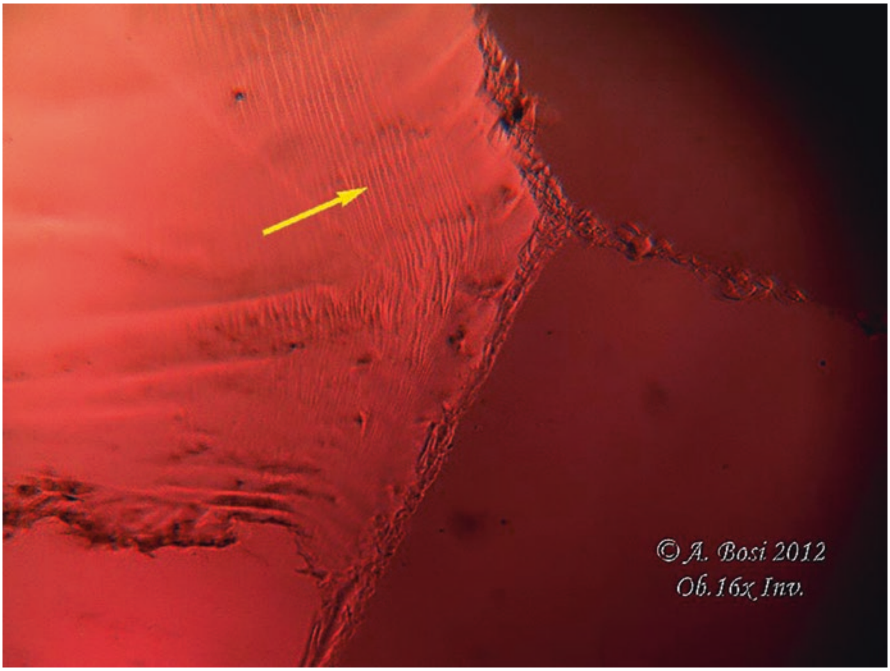


**Fig. 18.3** Synthetic ruby at a magnification of 16×; curvilinear striae of growth are clearly recognizable. (Courtesy of Dr. Andrea Bosi)

Another counterfeiting method consists of replacing the most precious gems with relatively common natural stones of lesser value or with artificial materials, such as glass paste, ceramics, or plastic resins. A technique that allows saving or replacing precious material with low-quality material is that of the doublet, which consists of creating a gem made up of two parts; the upper one is normally a precious stone that is affixed to a lower part of lesser value. Sometimes, doublets of very precious stones are made exclusively with less precious materials. The aim of this forgery is to increase the carats of the gem. The carat is the unit of measurement for precious stones and is equivalent to one-fifth of a gram, thus 200 mg (Rolandi and Cavagna 1996; Giarin 2012). In general, other characteristics being equal, the greater the weight of the gem, the greater is its rarity, and, therefore, the higher is its value per carat.

### *18.3.2 Analytical Techniques*

The analytical methods used to study the value of gemstones consist of the measurement of the refractive index, specific gravity, hardness, and caliber and the examination of all significant characteristics, such as color, clarity, brightness, cut, and distinctive signs (Rolandi and Cavagna 1996; Giarin 2012). In cases of imitation with synthetic products of the latest generation, advanced chemical and physical analyses are carried out on the gems to study their detailed features not detectable with superficial analysis or low-power magnification. These analyses envisage the use of spectroscopic but not destructive techniques, such as the following:

– Ultraviolet-visible-near infrared (UV-Vis-NIR) spectrophotometry; this technique registers the absorption phenomena of light radiation in the visible region of the electromagnetic spectrum (350–700 nm), in the near ultraviolet (200–350 nm), and in the near infrared (700–1100 nm). It is used mainly for the analysis of diamonds and the detection of their treatments; the determination of the geographical origins of emeralds, rubies, and sapphires; and the detection of some treatments on sapphires.
– Raman spectroscopy; this method analyzes molecular vibrations and/or rotations through the detection of the frequencies at which molecules diffuse radiation when they are subjected to laser radiation. It is used to identify heat treatments on diamonds and synthetic diamonds and various kinds of treatments on pearls, corals, emeralds, jades, and turquoises.
– Energy-dispersive X-ray fluorescence (EDXRF); this technique analyzes the elemental composition of a sample through the study of its X-ray fluorescence radiation. It is used mainly to establish the geographical origins of emeralds, rubies, and sapphires, detect the treatments of corundums and diamonds, and perform the analysis of pearls.
– Fourier-transform infrared spectroscopy (FT-IR); this method registers the vibrational phenomena of molecules when they are subjected to infrared radiation. It is mainly used to recognize resins and oils in emerald treatments and the treatments of opals, rubies, diamonds, turquoises, and jades and to analyze ambers.
– Photoluminescence spectroscopy (PL); this technique registers and detects the emission of photons from a material that is excited by electromagnetic radiation. It is used to detect the products of synthesis.

## 18.4 Precious Metals

The metals are elements distinguished by high thermal and electrical conductivity as well as by certain physical properties such as hardness and fusibility. Depending on their chemical stability, they are differentiated into precious metals and base metals. Precious metals are particularly resistant from the chemical point of view and possess exceptionally important physical characteristics, for example, ductility, which is the ability to withstand plastic deformation without rupture. In the commercial field, the well-known precious metals are gold, silver, platinum, and palladium.

Pure precious metals are too soft for the production of jewelry and objects; for this reason, they are alloyed with other metals that improve resistance and workability

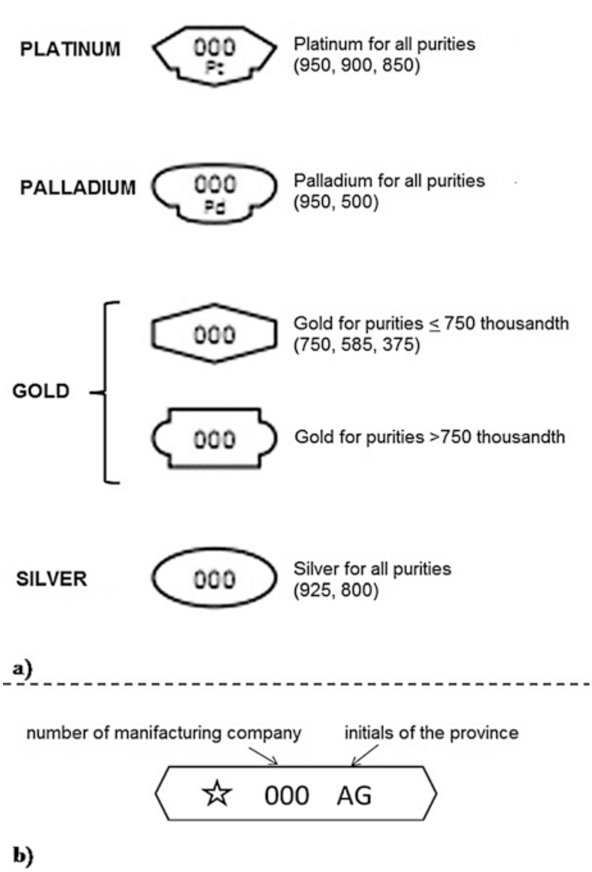


**Fig. 18.4** Scheme of purities of precious metals and polygon shapes (**a**); identification mark (**b**)

and may also change the color depending on aesthetic choices; for example, the different shades of gold result from the different percentages of other metals that are added to pure gold.

Since a superficial examination cannot verify the precious metal content in an alloy, Italian legislation prescribes that objects made with precious metals and their alloys should be compulsorily inscribed with at least two signs that constitute the so-called hallmark: the indication of the purity and the identification mark.

The purity is expressed in thousandths and highlights the relationship between the masses of the base metal alloy and the pure precious metal (Di Maggio et al. 2013; Capuano 2010). For example, an 800 alloy contains 800 parts of pure precious metal and 200 parts of other metals. The purity number is inscribed in a polygon, the shape of which indicates the pure metal in the alloy (Fig. 18.4a).

The identification mark is represented by a polygon containing a five-pointed star, a unique number assigned to the manufacturing company by the chamber of commerce and the initials of the province where the company resides (Fig. 18.4b).

The hallmark allows the manufacturer to be traced and therefore held legally responsible for the purity compliance declared for the item.

### *18.4.1 Methods of Falsification*

Generally, the falsification of precious metals occurs by substitution with less precious metals and subsequent plating with the metal to be imitated, as well as by employment of different alloy proportions compared to the specification of purity. Falsifications also involve the identification mark and the purity mark. Generally, the false hallmarks report incorrect purity marks, incomplete or missing indications of all the requested information for the precious object, numbers related to nonexistent manufacturing companies, etc. (Fig. 18.5).

Pure gold ingots are the subject of numerous fakes, as they constitute the standard of interbank trading. Years ago, the process used to falsify gold bars was to laminate with gold an equivalent volume of steel or lead. Steel and lead, however, have specific gravities less than that of gold; thus, the bars forged with this method weigh 60% less than the genuine version, making them easy to identify as fake. In the past decade, several falsified gold bars were discovered that were forged by the coating of tungsten blocks with a thin plate of pure gold. The choice of tungsten proved very advantageous because tungsten has a monetary value far less than gold but a similar specific gravity, so it is virtually impossible to distinguish a gold ingot from a tungsten forgery only by the weight/volume ratio. This forgery technique has provided an idea to those counterfeiters who had produced tungsten ingots using different methods.

Another type of falsification involves the forgery of ancient coins, which is particularly widespread all over the world. While the old fakes (e.g., the ones created during the Renaissance) have at present become documents of that period and therefore subjects of major interest, the modern falsifications are dangerous imitations that can turn into objects of fraud in sales if presented as genuine. Currently, the


**Fig. 18.5** False engraving of the hallmark on a silver object; the purity mark is not a perfect ellipse, and the numbers are distorted although the surface is flat and relatively easy to engrave; the identification mark is not clear, and it does not allow identification of the company legally responsible for the declared purity

phenomenon has taken a more criminal connotation, and the falsification quality has improved to the point of requiring an expert to discern the true from the false one. Furthermore, within numismatic collections, the phenomenon of alteration of original coins has developed to improve their quality and to make them more desirable on the antiquities market. These alterations include the closing of holes; the facing of the coin funds; the addition of an artificial patina, which means the concretions formed on the surfaces of ancient objects as a function of the aging; the reconstruction of the hair of a portrait worn for the burin; and the alterations of the legends.

### *18.4.2 Analytical Techniques*

Analytical methods for detecting precious metals are mainly the study of the hallmarks (the indication of the purity and the identification mark), which envisages the use of the stereoscopic microscope and/or the magnification lens and the analysis of the alloy and the plating. The last two methods involve different analysis procedures that range from quite straightforward and not invasive tests, such as the analysis of density or the so-called touchstone test, to spectroscopic techniques, used mainly to detect the exact chemical compositions of the alloys, the platings, and the cores. These methods include energy-dispersive X-ray fluorescence (EDXRF), scanning electron microscope and energy-dispersive spectroscopy (SEM-EDS), and inductively coupled plasma mass spectrometry (ICP-MS), which is particularly appropriate for white gold objects containing nickel or palladium.

The analysis of ancient coins, due to their high archeological value, involves nondestructive examination of the samples and their patinas. Generally, dating is performed on the concretions through $^{14}C$, observation with UV light, and nondestructive spectroscopic techniques, such as XRF, SEM-EDS, and FT-IR.

## 18.5 Fossils

Many specimens of fossils have considerable commercial value due to their rarity, conservation status, and antiquity. Parallel to the great market demand for these specimens, their manipulation and/or falsification has become increasingly common and has improved over time, reaching such high levels that in a general examination, even the experts are misled.

Parallel to the falsification of fossils, in recent years, there has developed a contraband trade in fossils involving in particular dinosaur skeletons or parts of them, tusks and teeth of mammoths, ammonites, and fishes. The clandestine nature of the smuggling of precious fossils makes it impossible to calculate the dollar amount of world trade, but reliable industry expert estimates suggest that it is approximately tens of millions of dollars a year (Fig. 18.6) (Simons 2010).


**Fig. 18.6** Smuggled egg of *Aepyornis maximus*, an extinct species of giant bird that lived in Madagascar from the Pleistocene to the seventeenth century, on its way to the United States and seized by Italian customs

In Italy, any activity related to paleontology is bound by the laws of the Ministry for Heritage and Cultural Activities that govern paleontological research and activities and prohibit collection by anyone who does not provide serious and adequate guarantees.

### *18.5.1 Methods of Falsification*

False fossils include both pieces reproduced more or less faithfully with various materials and pieces that have undergone a partial reconstruction or a touch-up, the addition of material details unrelated to the original fossil, or even recomposition in positions different from the original.

The counterfeiting of fossils aims to improve their appearance to tempt a buyer to purchase; for this reason, all fossils with commercial value are often subject to manipulation. The main forgery methods include the following:

- Reconstruction of missing parts; this forgery is performed when otherwise precious fossils have missing, ruined, or broken parts.
- Positioning of the fossil on a piece of matrix; this change occurs when fossils are found as loose materials in sediments.
- Assembly of pieces belonging to various individuals; generally, this forgery reproduces a specimen that is not in the same position as the original setting.
- Artificial coloring.
- Total reproduction.

The last method is usually carried out by means of a mold that can be produced using various materials; generally, appropriately colored resin is used. Resin is also used to make partial manipulations of the fossil. For example, during recovery operations, some types of fossil tend to detach from the matrix, as occurs, for example, with shark teeth; in these cases, the tendency is to reglue with resin the pieces that broke away, thus creating a falsification of the original situation.

### *18.5.2 Analytical Techniques*

The methods used for the study of the false fossils are paleontological observations and chemical analysis, which include:

- The identification and classification of the specimen
- The taphonomy, which is the study of processes occurring from the death of the organism to its fossilization
- The association of species, which is useful in the case of finding several specimens for understanding if it is a natural or an artificial assemblage
- Chemical and spectroscopic analyses, which aim to determine the nature of the materials from which the false specimens are composed
- Dating analysis using radioactive isotopes including carbon 14

## 18.6 Final Remarks

Although forensic geology is a useful tool for analyzing precious materials and works of art, there are some critical issues that involve analytical procedures and their management. The falsification of gems, precious stones, and fossils by means of latest-generation products of synthesis and artificial materials has reached such advanced techniques as to produce specimens almost identical to their natural counterparts, to the point that it is not easy to distinguish their differences. In such cases, the experts in geology, gemology, or paleontology must use very advanced and expensive instrumentation with the aim of providing probative evidence of falsification and a definitive identification of the synthesis.

Furthermore, as far as precious metals are concerned, the critical issue of the analysis is that the objects subjected to examination often require technical procedures that change the integrity of the samples. Indeed, forged objects hide the evidence of falsification beneath plating, which is removed in performing the analysis. This procedure modifies the state of the samples under investigation and requires appropriate applications of legislative tools.