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Archaeological tinned artefacts

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Archaeological tinned iron artefacts

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Introduction

Systematic use of radiography on iron artefacts prior to conservation treatment and access to modern methods of analysis have revealed that the process of iron objects tinning was known since Iron Age (450 BC) and widespread in Medieval Ages on a range of objects. The tinning layer of archaeological iron artifacts excavated from land sites, appears to be in most cases fragmentary, and partly mineralized. Its identification and localization is thus difficult and can lead to partial destruction of the residual plating during the process of mechanical cleaning. Common desalination treatment for iron archaeological items such as alkaline sulphite is contra-indicated for this kind of objects. In consequences, choices of restoration and proper treatments of conservation must be chosen.

History of tinning

Tinning is one of the techniques of enhancing the visual appearance of iron and improving its protection against corrosion.

Tinning refers to coatings of tin or tin alloys on other metallic objects. The coating may be of almost pure tin or of a low melting point tin alloy, the alloying material being mainly lead [1]. Tinning was performed for three main reasons, the first being aesthetic, the second technological and the third relating to tin non-toxic and tasteless properties [2].

- The aesthetic reasons are associated with the similarity of appearance of tinned surface to silver. Tinning was therefore used as a decorative technique imitating silver. Pliny (I century AD) considered tinned objects to be indistinguishable from silver [3]. It was performed as a continuous coating on the whole (fig.1-2) or part of the surface of the objects (fig.3) or as an inlay (fig.4).

- Tinning provides a good corrosion protection of iron surface. This function was perfectly known in Medieval Times as the monk Theophilus (XII th century) describing the making of a wind machine says: "...you should also make strong iron bindings, tinned inside and out so that they cannot be destroyed by rust" [3].

Tinning also gives a suitable surface for soldering [4] (fig. 5a-5b).

- Tinning also serves as a barrier to prevent contamination of the food from iron. It is non-toxic and tasteless [2]. According to Pliny, tinning was used by the Gauls to coat the inside of copper vessels to prevent tainting of food [5]. The tinned iron spoons and tin plated nails connected with wooden vessels [4] from York (Xth century) have probably been tinned for the same purpose. Many harness bit were also tinned, which suggest that tinning of this kind of objects might have been done to isolate the iron from the mouth of the horses.

There are numerous archaeological evidence that tinning of bronze alloy was performed as early as Bronze Age (2000 BC) [6] widely used by the Celts, the Romans, the Merovingians, and the Saxons, but little is to be said about the early history of tinned iron. But radiography, conservation and analysis in the British Museum of an Early Iron Age (450-500 BC) dagger from Spain, has showed that the handle was plated with tin [7].

An Iron Age harness bit from Bredon Hill in Gloucestershire shows also remains of tinning [8]. Rapin mentioned evidence¹ of celtic tinned iron objects (scabbard, belt fittings from Gournay-sur-Aronde) [9] making one speculate that there are surely other examples of tinned iron from Iron Age lying unrecognized in our museums. Tinned iron objects being more perishable than tinned copper, the likelihood of finding early examples is correspondingly reduced.

There is no evidence of tinned iron during the Roman Period, which is surprising as we know that this method is described by Pliny in his Natural History [5] to coat copper cooking vessels and is believed to have been invented by the Gauls.

Evidences of tinned iron are more frequent at the Medieval Period suggesting that this technique was often used at this period. Jope mentions early examples of tinned iron spurs from the 8-10th centuries [10].

Further evidence of tinned iron (spoons, spurs, dress-fitting, box-fittings, nails) generally very well preserved in consequences of the waterlogging of the deposits, were found at the Viking excavations of Coppergate in York [4]. This finds prove that the technique of tin plating was extensively performed by the Vikings since the 9th-10th century AD.



In Bohemia, there are also evidences of tinned iron objects as early as the 10 th century. Tinned iron spurs were found in Roztoky Žalov, Kanín [11], Klecany, Čáslav, Nymburk [12].

The metallic handle of knives from the 10th century excavated in Klecany, Budeč, Bášt [13], and later from Levý Hradec Žalov [14] were also tinned. Engraved ornaments on the surface of a 14 th century sword or sheath of scabbard found in Moravia were filled with tin [15].

Furthermore, tinned buckles and belt fittings were also evidenced from the 12th and 15th centuries [16].

By the eleventh century, tinning of iron seems to be a common practice. A clear description of the process was written by Theophilus [17]. Tinning seems to be practised in the Middle Ages in Europe on a range of iron objects.

In France, in the settlements of the lake Paladru [18] [19] dated from the X-XI th century (Colletière-Charavines), tinned iron harness bit, spurs, buckles, keys, ear-pendants, iron fittings were found.

The Ashmolean Museum at Oxford has a collection of tinned iron spurs examined by Jope [10] which shows that the tinning of iron spurs from the 10 th to the 17th century was a common practice.

Other examples of tinned iron are two thirteenth century keys from South Wales and Canterbury [20]. Hedges also reports that tinned iron drinking-vessels are mentioned in the city of Nürnberg's architect's book at the 15th century among the list of household articles.

The tinning of hammered wrought iron sheet is believed to have been first practiced in Bohemia in 1240 [21], but it seems more probable that the beginning of the manufacturing of tinned hammered wrought iron began in the 14th – 15th century in Nürnberg or in Wunsiedel in Germany. By the middle of the seventeenth century, Saxony became the most important centre of this industry and tinplates made there were imported to other countries [2]. The tin-plate industry expanded in the mid-18th century with the advent of the rolling mill [6] and became rather common for every day life objects and covering of roof.

Ancient tinning methods

There are several ancient methods of tinning. The characteristics of the tinning layer (thickness, porosity, surface appearance, adhesion) and its conservation depends of the techniques used for its preparation. The techniques most likely to have been used for the tinning of iron in Ancient Times are hot-dipping tinning, wipe-tinning and fusion-plating.

Hot-dip tinning

The majority of tinned iron objects were probably coated by hot-dipping.

The method was described by Theophilus [17]. The object being coated would have been immersed for several minutes in a bath of molten tin or its alloy covered with a suitable flux (resin or tallow) at about 260°C, and excess tin allowed to drain off. A clean, degreased, oxide free surface would have been required. Filing the surface of the object immediately before immersing would have been common

operation before tinning as described by Theophilus² [3]. The reference to filing is very interesting because on a number of tinned iron objects, it is possible to observe striations on the surface. The filing, although intended primarily to remove oxides from iron, would also give a better mechanical adhesion by keying the tin to iron [3]³.

The surface prepared in this manner has a smooth reflective, silvery appearance, a thick layer of tin. The layer is irregular, excess of tin is present in the incised decorations or corners.

Wipe-tinning

Wipe-tinning method could have been used alternatively, especially for objects which were to be coated only partially (from one side) or for object too big to be immersed. This method involves applying solid tin or tin-lead alloy to a cleaned oxide free surface of iron object protected by flux, heated to a temperature significantly above the melting point of the coating metal. The excess of molten tin can be physically wiped over the surface with a cloth [6].

This method was widely used for the tinning of the inner side of copper alloy vessels by the Gauls as reported by Plinius [5] but no mention of its application on iron is made. Brown [22] describes the method also used in tinning hollow ware: "The metal article is first thoroughly cleansed by pickling it in dilute muriatic or sulphuric acid and then by scouring it with fine sand. It is then heated over a fire to about the melting point of tin, sprinkled with powdered resin, and partly filled with melted pure tin covered with resin to prevent its oxidation. The vessel is then quickly turned and rolled about in every direction, so as to bring every part of the surface to be covered in contact with the molten metal. The greater part of the tin is then thrown out and the surface rubbed over with a brush of tow to equalize the coating; and if not satisfactory the operation must be repeated". He adds that the vessels usually tinned in this manner are of copper and brass, but with little care in cleaning and manipulating, iron can also be satisfactorily tinned by this manner. The vessels to be tinned must always be sufficiently hot to keep the metal contained in them thoroughly fused.

An alternative method would be the use of a tin rod rubbed over the cleaned oxide free, fluxed object, heated to a temperature well above the melting point of the coating metal. Two rods of tin with melted tips have been found in York [4].

Jope and Harrison mention another method called fusion-plating in which, the fluxed surface may have been sprinkled with tin filings [10], or tin powder [7], and then heated.

The surface prepared by wipe-tinning method shows traces of cloth used to wipe the tin over the surface, traces of touching up and has a dull appearance.

Electroless plating

The oldest mention of this method dates from the 18th century and is described by Diderot and Alembert, for the tinning of brass pins [23].

The process was carried out by immersion of the copper, bronze or brass objects in a boiling solution of potassium



bitartrate, a by-product of wine fermentation, together with pieces of metallic tin or foil [6].

Thouvenin describes the method precisely according to the explanation of the Diderot and Alembert encyclopedia [24].

In a copper boiler with a top, thin circular tin foil of about 0,5 mm of thickness are placed on an iron crossbar support. Between them, layer of pins are laid down. The boiler is filled with pure water in which one kilogram of white gravelly ashes is added⁴. The whole content is then boiled for 4 to 5 consecutive hours adding periodically water to compensate the evaporated water.

Instead of tin foil, granules of tin can also be used mixed to the objects according to the encyclopedia of Roret (19th century). It is also recommended at this time to add several drops of tin chloride to make the operation easier.

Thouvenin is convinced that this method was known in Antiquity and would have been used to tin-plated coins and fibulae from the late Roman Empire, as well as Merovingien buckles of belt for instance as this method produces a very thin and regular coating adapted to fine objects and mass treatments [25]. He reproduced experimentally this method on copper alloy and was successful. Half an hour was enough to whiten a little object [26]. He did not try this method on iron. This method is however, in principle possible on iron. Le Breton also describes the method of currentless tinning and gives precise recipe for the plating of copper and ferrous alloy [27]. Our experimental tinning by this manner on iron has not been however really successful until now with respect to the quality of the deposited layer [28].

Mercury/tin amalgam

Tin could have been applied by amalgamation. The process consisting in applying to the clean and dry metallic surface, a film of pasty amalgam of tin with mercury, and then exposing the surface to heat, which volatilizes the latter, leaving the tin adhering to the metal [22].

Corfield mentions [3] that the Leyden Papyrus from the 3th century AD (recipe 5) gives a formulation for tin amalgam. A decorated Chinese bronze dagger gives evidence that ancient amalgam tinning was performed for ornamentation at about 475-221 BC [29].

It is doubtful though, that this method was used for complete plating of iron as the fusion or hot-dipping methods were so simple. Amalgamation may have been used for partial tinning of other metals for decorative effects as inlays.

Alteration of buried tin-plated iron objects

In anaerobic conditions of a waterlogged site, tinning is very well preserved. The tinned iron objects from Coppergate, Charavines-Colletière show a continuous, thick, metallic coating of tin on their surface. But in prevailing wet aerobic burial⁵ environment, the tin coating of ferrous archaeological objects is most of the time fragmentary and generally in a poor state of conservation. Completely covered by a thick layer of iron corrosion products, it can only be detected by radiography. Sometimes in some places still preserved in a metallic form, but most of the time displaced, residual or

maintained in situ as tin oxides in which some metallic spots of tin can be detected under scanning electron microscope (SEM). This can be explained by the corrosion process of the tin coating on buried iron (fig. 6). After manufacture, the iron object is protected by the physical barrier of tin whereas tin is protected by a passive layer of stannic oxide SnO_2 which forms on the metal on exposure to the air (stage I) [31]. In absence of substances capable of forming with tin soluble complexes, tin will resist corrosion perfectly in moderately acid, neutral and slightly alkaline solutions, free of oxidizing agents [31]. During its burial, since the vast majority of natural environments are in the pH range of 4–9 [32], the tin is in a passive state.

Corrosion of iron starts when the coating of tin is damaged by mechanical or chemical means (scratch, wear, defects, effects of salts, impurities, heterogeneities, O_2 , pH) (Stage II). Water, salts and oxygen are in direct contact with iron and an electrolyte is forming. Tin being cathodic to iron substrate, iron will corrode preferentially until the two metals are electrically coupled (stage III). When the contact between iron and tin ceases, the tin will start to corrode independently (Stage IV). The residual tinning layer as shown by the examination of the cross-section of a heavy corroded tinned iron [34] can be fixed in its original location by products of corrosion of iron (fig. 7-8), or displaced by them in the upper strata of products of corrosion of iron (Stage V).

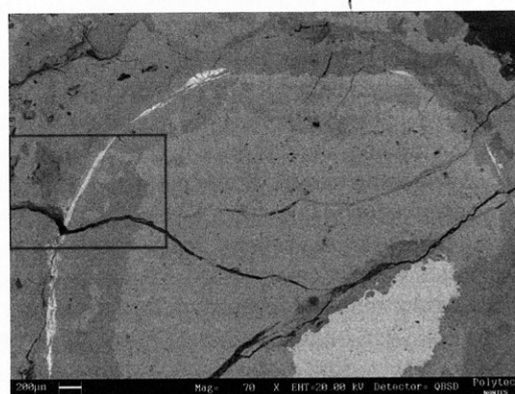


Fig. 7: cross-section of a tinned-iron buckle from Montsoreau, France Medieval Age under SEM (70X). J-B Mémet/ Arc'Antique (Leroux 2002).

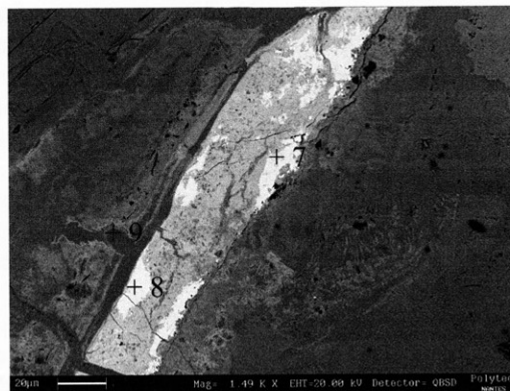


Fig. 8: Magnification of Montsoreau's buckle (1490X). The EDX analyses an important rate of tin and iron on spots 7 and 9. The spot 8 reveals exclusive tin metallic compound. Picture J-B Mémet/ Arc'Antique (Leroux 2002)



Identification of the tin plating prior conservation

It is difficult to distinguish directly tinning on archaeological iron object, because the plating is covered by a thick layer of corrosion products of iron and most of the time is not visible before restoration (fig.9). The use of radiography for examination of iron artifacts prior to cleaning is the first step indicating an eventual presence of metallic coating (fig.10). Comparison with typology of objects usually tinned can also be of precious help to determinate the chance of finding a tin-coating on the artifacts. Chemical analysis must be performed to confirm the identification of the tinning.

Comparative observation with experimental tinned material obtained by different methods can identify the process of tinning used by ancient metal craftsmen. The technological identification of the tinning is important from both the curatorial and conservation viewpoint.

X-Ray Radiography

Most of the conservators are familiar with the bright outline which surrounds the profile of a tinned iron object on the radiograph. This bright outline is resulting from a higher absorption of the X-rays which are going through the tin coating. Two sheets of similar thickness of tin and iron do not appear on radiography in the same way because their atomic number is different ($Z=26$ for iron and $Z=50$ for tin).

The tin-coating or the remains of the tin-coating appears on the radiographic image [30] when the tin coating is thick enough. If the x-rays are going through a denser material, thicker, or having a higher atomic number than the tin layer then, the radiographic sign of the coating will be too weak to appear on the X-radiography. This is the reason why, the radiographic image of the coating appears rather on the outline of the object where the X-rays are going through the coating on his greatest thickness [30].

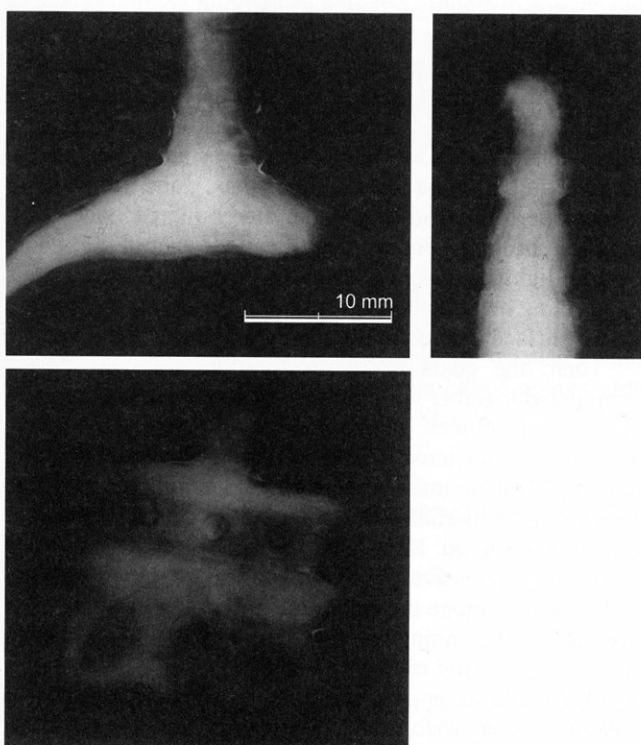


Fig.11: X-radiography of tin plated spurs (details).

This bright outline is usually discontinuous, of more or less regular thickness (fig.11). It is usually underlying the outline of the object and follows the incised ornamentations. It is located under the external layer of corrosion products and on the level of the original surface.

The tin coating appears more clearly when it is situated within iron corrosion products because they are less dense than tin or corrosion products of tin. It is therefore more difficult to see the characteristic outline of the coating if it is lying directly on metallic iron. The radiographic sign of the tin-coating is present even if the plating is residual and is formed only by oxides of tin, because tin oxides are denser than iron corrosion products. This explain that, although the tin plating is clearly visible on the X-radiography, it may be present only in the form of oxide of tin and exceptionally in metallic state, especially on archaeological objects from Early Medieval Period. This of course complicates its conservation and identification as oxides of tin are not visible with standard means of observation (direct observation, stereomicroscope etc.) and their visualization is possible only with electron microscope.

Radiography is the first step to detect tin-plating. But it is only by analysis that we can be sure that the thin white outline on the X-Ray is truly tin or not, as it can be the result of other metallic coating (copper-plating, silver-plating, gilding) or might also be the result of overheating in the case of iron exposed to fire [30].

Typology of tinned Archaeological Iron Objects

Knowing the type of objects on which tinning was evidenced until now, helps to have an idea on the probability to find residual tinning on archaeological ferrous objects.

- ***In Iron Age***, tinning was evidenced on weapons: **hilt of a dagger** [7], horse equipment: **harness bit** [8].
- ***In Early Medieval Age*** were tinned pieces of dress-fitting - **buckles, buckles-plates, back belt buckle, strap-ends, pins**, jewellery - **ear-pendant, ring**, riding equipment - **spurs and buckles**, structural ironwork and fittings - **box-fittings and decoration-plates, nails** (in particular associated with wooden vessels), **keys, spoons**, weapons - **sword pommel, handles of knife, sword blade or scabbard** horse equipment - **bridle bit, mouthpiece bit, elements of harness or bridle, decorative elements of harness** [4], [18], [19], [10], [13].
- ***In Late Medieval Age*** there is evidences of tinned riding equipment - **spurs, drinking vessels, wrought iron sheets** (tinplates), **cutlery-knives** (handle, rivets, tin-inlaid cutlers-marks and inlays on the blades) [10], [20], [21], [34].

Stereomicroscopy

Observation under stereomicroscope is a good technique to give an overall view of the surface of the object, providing information on areas of surface plating visible if well preserved, underlying and overlying corrosion but it is rarely sufficient to detect residual mineralized tin-plating on highly corroded archeological ferrous objects before treatment.

Chemical analysis

The identification of tinned surfaces on iron archaeological objects is relatively simple by using following analytical methods:

- *X-Ray fluorescence analysis (XRF)* can identify rapidly the presence of tin with no damage to the often fragmentary remains of tinning, but will give only approximate information about content of lead if present in the alloy.
- *Scanning electron microscope (SEM) plus microanalysis (EDX)* gives more precise results of the composition of the tinning layer (fig.12). It is a non-destructive method, but limited only to a small artefacts and time consuming.
- *Spot tests* can also determine the presence of tin plating on an object, if the conservator does not have an access to above mentioned preferable analysis. A rather simple spot test using cacotheline can be used. Cacotheline ($C_{21}H_{21}N_3O_7$) is a complex organic compound related to brucine [36] acting as an oxidizing agent towards stannous oxide (II). Reduced, the cacotheline turns purple. This method was tested in the frame of a master degree practical work in conservation and restoration at the University of Paris I Pantheon-Sorbonne [37]. To counter the fact that this reagent reacts only with stannous oxide, a reduction agent (Zn), necessary to reduce stannic oxide (IV) (SnO_2) to stannous oxide (II) (SnO) was added in the procedure (the residual tinning layer containing mainly oxides of valence IV. No interferences with iron ions were noticed. The saturated cacotheline solution is made by dissolving of 0,25 g cacotheline in 50 ml of distilled water. The corner of a filter paper is dipped in hydrochloride acid 10%w/v and put in contact with the surface to test for approximately 30s under binocular to control the application of acid on the object. The objects must be immediately rinsed in distilled water and then dried. The filter paper is put on a glass plate. Powder of zinc is spread on it and left for wait 30s. A drop of the solution of cacotheline is then put on the paper. The test is considered positive if the paper turns immediately (within 3s max) purple.

Metallographic examination

Cross-section can evidence presence of residual tinning and allow identification of specific structure intermetallic phases characterizing the technique of tinning used (eg: the θ intermetallic compound $FeSn_2$ is typical for the hot dipping tinned objects). It is though a destructive method and applied on archaeological object with residual tinning layer, it does not have sense unless the object can be sacrificed to study the state of alteration of the plating within the products of corrosion.

Comparative experimental tinned material

By characterization of various tinned artifacts and comparative experimental tinned material reproducing different manufacturing processes, it should be theoretically possible to identify the technique of tinning used by ancient craftsmen. Each method has characteristic features for identification purposes [24, 28].

The **hot dipping** method is characterized by a thick layer

(10-20 μ m), its irregularity, the excess of tin in the incised decorations, the use of tin or tin/lead alloy, the presence of a θ intermetallic compound $FeSn_2$ formed by diffusion of iron into the tin, the presence of fine grooves, or striations on the surface under the tin-coating resulting of the filing of the surface to remove oxide layer from iron before immersion in molten tin, and a smooth reflecting and silvery appearance.

The **wipe-tinning method** is characterized by the thinner layer than in the case of hot dipping, traces of cloth used to wipe the tin over the surface, traces of touching up, the use of a tin or tin/lead alloy and a dull appearance of the layer.

Finally the tin plating obtained by **electroless plating** is characterized by a very thin (5 μ m), homogeneous, and regular layer of tin, highlighting the fineness of the decoration. The tin layer is of pure tin. It is porous. The surface is dull in appearance if not polished and the plating is easy to scratch and mark.

These features obvious on fresh tinned samples are nevertheless, not easy to take in account on degraded archaeological tinned iron objects as the corrosion and physical degradation during the use, the burial and the conservation treatment affected considerably the initial tinning layer.

Treatment of conservation

The restoration and conservation treatment of tinned iron raises several problems. Before the 15th century, in classic terrestrial burial environment, the tinning layer on iron is rarely well preserved in a thick metallic state. It is certainly visible on the X-ray, but appears to be extremely fragmentary, rarely in a metallic form. The first task of the conservator is to detect and identify the plating of the artefact on the object, cleaning as carefully as possible a little area (fig.13-14) chosen according to the x-ray where the chance of finding remains of metallic coating seems to be the most probable (thickest layer, preferably in protected area e.g. incised lines, corners) (fig.11). The best method to reveal the original plated surface is mechanical cleaning with air abrasion equipment (sandblasting), using glass micro-spheres of 0-50 μ m of diameter as abrasive powder. The pressure must be low (2-3 bars max.), and the cleaning process performed ideally under stereomicroscope if not, regular checking under magnification should be done. Natural lighting makes it easier to distinguish the remains of a tinning metallic layer. Very often, striations are present on the surface where the tin plating is lying.

Then, the goals of the restoration must be clearly formulated together with the curator or the archaeologist in charge of the object.

- If the object must be exposed, a mechanical cleaning with air-abrasion must be performed, keeping in mind that it will lead to partial destruction of the tinning layer if it is badly preserved. If metallic tin is revealed, it should be protected progressively by local application of acrylic resin 30% w/v in acetone during all the process of cleaning. The presence of the tinning layer must be well documented with X-radiography and results of analysis.

- If the object is not going to be exposed then local cleaning can be performed to allow its archaeological study and documentation. Residual tinning will be then preserved in the uncovered areas in the iron corrosion products.



Stabilization of the iron is equally a problem. The use of alkaline sulphite is contra-indicated because of the high pH involved which dissolves tin. Experiments using modern tin plated cans have showed that after immersion of 15 days in alkaline sulfite, all the tin was destroyed [30]. Washing with distilled water often results in redeposition of iron oxides on the surface which have then to be removed with consequent danger to the fragile plating [3]. The methods of desalination in water solution of ascorbic acid and hydrazine [38] might be interesting alternatives of treatment which should be tested on experimental tinned sample. Remains of tinning in a metallic state have been revealed on objects treated by these methods [16, 12], but we have no idea of the original state of the tinning before treatment and of the effect of the treatment solution on the plating until now. Comparative study with tinned experimental sample should be performed. Another alternative stabilization method to evaluate could be the use of hydrogen plasma treatment.

Application of inhibitors (e.g. tannin) or control of the environment (max 30 % HR) can also be indicated for active tinned iron.

Conclusion

The evidence of tinning relies in the hand of the conservators, as it is only at the conservation stage that tin can be detected. We realize, how important is the use of X-radiography and chemical analysis prior conservation treatments in detecting and identifying often residual and fragmentary plating, hardly visible by standard means of observation with stereomicroscope. The responsibility of the conservator is double. Firstly, he is responsible for the detection and identification and documentation of all materials present on the objects revealing part of archaeological information and secondly for the conservation on the long term of the object and associated materials. We see that identification of the tinning layer is technically possible, whatever its state of preservation, but its conservation is more problematic and further research has to be conducted especially for desalination treatments whereas choices must be made in cleaning entirely or partly the object to preserve the remaining tinning layer.

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Summary

Tinning of iron is a technique used since the second half of the 5th century BC by ancient craftsmen. It was used as a decorative technique imitating silver, as a corrosion resistant barrier, as a suitable surface for soldering, and for its non-toxic properties. Usually badly preserved and hidden under iron corrosion products, it is though visible on X-radiography and can be identified by chemical analysis. Its conservation poses problems during mechanical cleaning and desalination treatments.

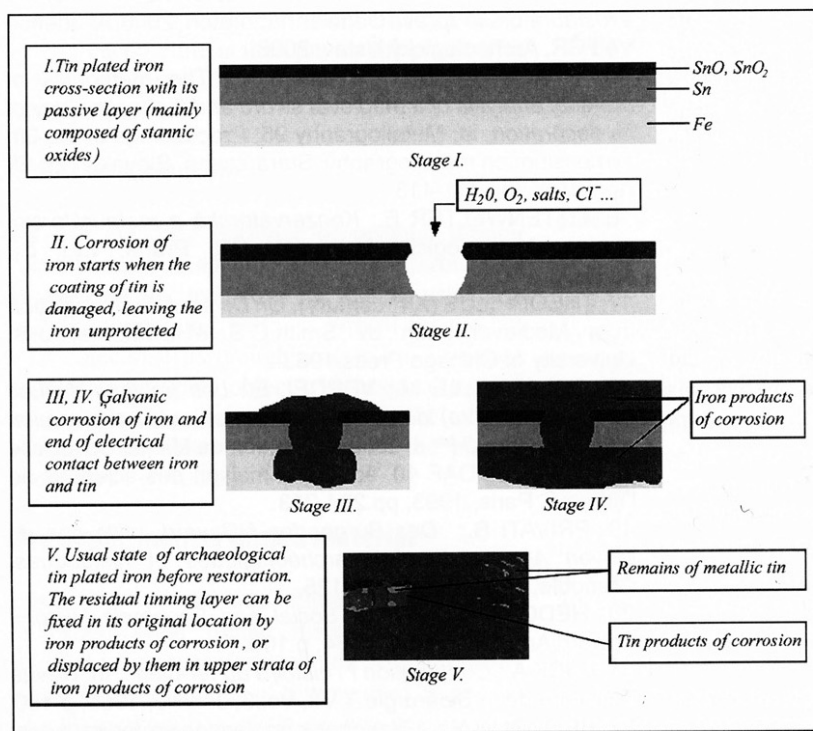


Fig. 6: Stages of degradation of archaeological tin-plated objects (Leroux, 2002) [30]

Viz obrazová příloha / XI.



Archeologické nálezy pocínovaných železných předmětů

Archaeological Tinned Iron Artefacts



Obr. 1: Železné kování z Prahy, 15. Století, celkově pocínovaný předmět.
Fig. 1: Iron fitting from Prague, 15 th century, entirely tinned object.



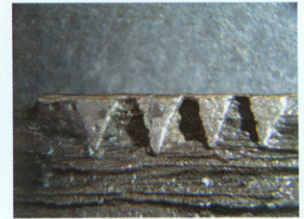
Obr. 2: Ostruha, Praha 15. Století.
Fig. 2: Spur, Prague 15 th century.



Obr. 3: Nůž z Levého Hradce, 10. Století.
Fig. 3: Knife from Levý Hradec 10 th century [14].



Obr. 5a: Nůž z Opavy, 14. Století.
Fig. 5a: Knife from Opava 14 th century.



Obr. 5b: Detail dekorativního cínování a pájení.
Fig. 5b: Detail of the tin decoration and solder.



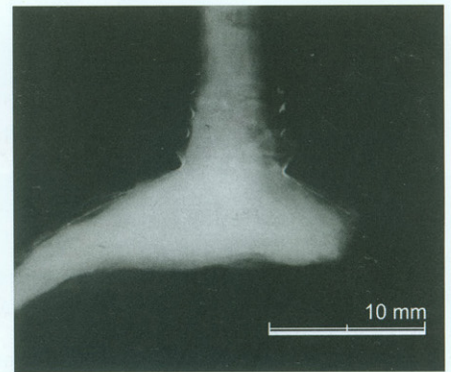
Obr. 4: Nůž z Londýna, 14. Století s cínovým rytím [39][35].
Fig. 4: Knife from London, 14 th century with a tin inlaid [39][35].



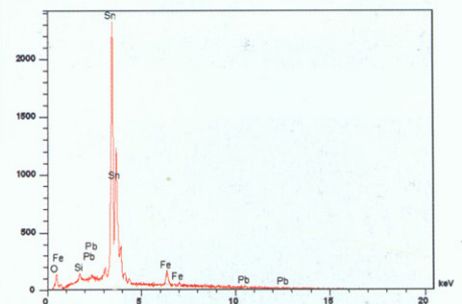
Obr. 13: Zvětšený detail ostrухy se zbytky pocínování.
Fig. 13: Detail of the spur under magnification showing remains of tinning.



Obr. 14: Zvětšený detail ostrухy se zbytky pocínování.
Fig. 14: Detail of the spur under magnification showing remains of tinning.



Obr. 11: Rentgenové snímky cínovaných železných ostrух (detaily).
Fig. 11: X-radiography of tin plated spurs (details).



Obr. 12: Spektrum SEM/EDX analýzy zbytků cínování ostrухy z Roztoky-Žalov.
Fig. 12: Spectrum of SEM/EDX analysis performed on remains of tinning from the spur from Roztoky-Žalov.