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Theophilus and the shrine of Vitus- A goldsmith's technique in the mirror of ancient references

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Abstract

This investigation of a Romanesque reliquary dating about 1200 AD, is a comparative study of Theophilus´ treatise *On divers arts* and other treatises, and the methods used for manufacturing this shrine. Scientific analysis of the shrine's enamel and niello work reveal quantities of boron in the enamel, which are absent in the niello. A bibliographical survey documents acquaintance and use of borax in Greece, in the Arabic and European middle ages until today. The possible use of borax in niello and solder work in the time of the manufacturing of the shrine is presumed. According to present knowledge, two enamel sheets of the shrine can thereby dated to modern times.

Résumé

Cette étude d'une relique romane datée d'environ 1200 AD cherche à montrer le rapport entre les méthodes de production de l'orfèvrerie et les formules des sources techniques de la même époque, comme *De diversis artibus* de Theophilus Presbyter. Les analyses scientifiques de l'émail et de la nielle détectent des quantités marquées de bore dans l'émail, mais pas dans la nielle. Une étude des sources documente sur l'usage et sur la connaissance historique du bore. Le résultat est la datation de deux plaques émaillées aux temps modernes. Cette recherche démontre la possibilité de la datation par la détermination des quantités de bore, en cas échéant.

Keywords: borax, flux, enamel, niello, medieval goldsmith technique, Theophilus

1. Introduction

Reliquaries make up a significant part of collections of medieval sacred goldsmith's work. This research work deals with the so-called *Vitusschrein*, a Romanesque altar-shaped reliquary from the former Benedictine monastery Willebadessen near Paderborn (Westphalia, Germany). Investigation of the manufacturing methods offered the possibility to research a material, which often eludes scientific analysis: borax. The study is an enlarged part of a diploma dissertation at the State Academy of Art and Design in Stuttgart, Germany (Grieb 2004).
After a short description of the shrine, the study focuses on borax and deals with the manufacturing process of the shrine. Historic treatises are dealt with, which document the circumstances of trade and availability of borax in Europe and the usage as a flux in medieval metallurgy and goldsmith's work. Based on contemporary references, the reason for the confusion about this material in these times is analysed. Thereby, some myths surrounding this material will be unveiled.

2. Description of the shrine

This goldsmith's work is of special importance, because it was manufactured in an area near the monastery Helmarshausen, where the famous goldsmith Rogerus of Helmarshausen operated his workshop. Dendrochronological investigation as well as historical observation suggest a manufacturing date no more than 70 years after the time of Rogerus. The shrine of Vitus is dedicated to a monastery not far away from Paderborn, where the well-known reliquary of Kilian and Liborius is kept. It is maybe the most famous of Rogerus' works. In addition to this, the monk Theophilus Presbyter, author of the goldsmith's treatise *De diversis artibus*, seems to be identical with Rogerus. It can be suggested, that the goldsmith of the *Vitusschrein* was aware of this treatise and maybe used his recipes.

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Figure 1. The shrine of Vitus.

Figure 2. The lid of the shrine of Vitus.

The shrine is square-shaped with a lateral length of 28,8 cm, a width of 16 cm and a height of about 20 cm. The shape, which emphasizes the horizontal and vertical lines reminds us of an altar, but the shrine never had this function.

It is constructed of a case made of oak, sheathed with chased, gilded silver and copper sheets. The sheets are decorated with niello and enamel. Around the middle part (stipes), the twelve apostles are depicted; the lid shows Jesus Christ in the centre accompanied by the Holy Mary and the Holy Vitus. In the corners, the four evangelists can be seen.

Gilded copper sheets, which are decorated with enamelled inscriptions, cover all sides of the shrine. For the decoration, the technique of email champlevé was employed. Two sheets on the lid are decorated with tendril motives carried out in blue email champlevé.

Figure 3. The shrine's left enamelled sheet.

Figure 4. Detail of the nielloed sheet below the figure of Jesus.

The tops of the left sheet tendrils are decorated in turquoise colour. Two gilded sheets inscribed with prayers in niello complete the motive of Jesus Christ.
These nielloed sheets in combination with the two enamelled sheets of the lid are the major subjects of this study.

3. Analysis of the shrine

Scientific research on the shrine of Vitus focussed on gaining relevant information to help understand the manufacturing process and history of the shrine. It was of main interest to find evidence for the dating and the authenticity of separate constructional parts. Detailed analysis was carried out on the appliqués of the lid, particularly on the enamelled and the nielloed sheets, as later alteration or trimmings were suggested.
The crowded arrangement of the lids decoration is remarkable, as Figure 2 demonstrates. The surface of the enamel is not worked down to the level of the base metal as usual, but shows an untypical fire-glaze. This stands in contrast to the enamel of the shrines body. The decoration of the sheet metal as a background was carried out using a decoration technique (quaver engraving) which is completely untypical for medieval times. The arrangement of the two tendrils is also not characteristic for medieval times. Art- historical investigation suggests a product of the art noveau movement (Kötzsche in: Grieb 2004).

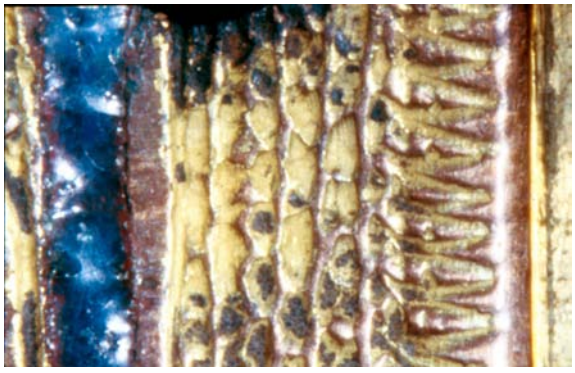

Figure 5. Detail of the right enamelled sheet.

However, XFA-analysis of the enamels did not point to a modern work; the glass compounds were nearly corresponding with the typical Romanesque soda-lime-silica-composition defined by Freestone (1993) as demonstrated in Figure 6.

Sample	SiO_2	Al_2O_3	MgO	CaO	MnO	PbO	Na_2O	K_2O	CT	Reference/ analysis
Enamel glass typical soda-lime-silica glass		~2	<1	~7	<1		~15	<1	0,5 - 1	**Freestone** (1993: 39)
Shrine of Vitus lid, left enamelled sheet	65,98	2,33	0,48	7,57	0,54	0,77	14,06	0,61	0,82	**U. Schüssler,** University of Würzburg
Shrine of Vitus lid, right enamelled sheet	67,76	2,71	0,48	7,36	0,85	1,24	14,00	0,63	0,87	**U. Schüssler,** University of Würzburg

(weight per cent.)

Figure 6. Typical Romanesque enamel compound and selection of XRF-analysis of the lid's two enamelled sheets.

Sample	elements	analysis
Shrine of Vitus niello	silver, copper, lead (**major elements**) gold, bismuth, quicksilver, tin, iron (**trace elements**)	**E.- L. Richter,** State Academy of Fine Arts, Stuttgart
Shrine of Vitus lid, right enamelled sheet	sodium, silicium, calcium, magnesium, aluminium, cobalt, tin, lead, copper, silver, gold, quicksilver, iron, manganese, antimony, boron	**E.- L. Richter,** State Academy of Fine Arts, Stuttgart

Figure 7 Emission spectroscopy analysis of the niello and the right enamel sheet's glass.

Analysis carried out with Optical Emission Spectrography (OES), which is able to detect light elements, showed distinct amounts of boron. Boron is added to the molten glass in the form of its compounds; in former times, mainly borax was used. The analytical result is somewhat surprising, because Theophilus and other authors of that time did not mention any additives of this origin in the enamel glass.

Subsequently, an OES-analysis of the nielloed sheets was carried out, but no boron could be detected. If the goldsmith who made the shrine of Vitus followed Theophilus' recipe, boron should have been present. Theophilus mentions the fusing of niello in his third book, chapter 29:

„When you have filled several quills [with the niello powder] *in this way, take the resin called borax and grind a small piece of it with water in the same pot, so that the water is rendered just turbid from it. Wet the place you want to cover with niello with this water first; next, take the quill and with a light iron rod tap out the ground niello carefully over the place until you have covered it all, and do the same everywhere. Then heap together well-burning coals and put the bowl into them, covering it carefully in such way that no coal is placed over the niello or can fall on it."* (Hawthorne and Smith 1979).

Most editors translate the formulation "*...accipe gummi, quod vocatur parahas...*", (named "*barabas*" in the manuscript of Wolfenbüttel) as "take the resin called borax" (discussed in: Grieb 2004).
In theory it should astonish us that the niello compound does not seem to contain boron. How can this discrepancy be interpreted? On the one hand, a significant content of boron was found in the enamel-glass, although not verified by Theophilus, alternatively there is a lack of boron in the niello, where he describes the use of borax. To clarify this question it appears necessary to look into the matter of borax.

4.1 What is borax used for? –General remarks on the use of borax as a flux

Borax, named chemically as sodium tetraborate decahydrate, is used in goldsmith work in the form of the pentahydrate, called "jewellery borax". Because of its good ability to dissolve metal oxides, it is used in many high-temperature processes, such as soldering, refining metals, or in nielloeing where obstructing

interfering metal oxides have to be removed. On the one hand borax dissolves metal oxides and removes them from the work piece, but also, it forms a glassy coating which prevents the reaction with oxygen.
Borax, in the form of boron oxide, has another function as a component in glass used for enamel inlays. Boron oxide acts as a network former and as a flux. The term "flux" in glass technology, means an alkaline compound which lowers the melting temperature range of a glass. It raises gloss and physical stability, lowers the fusion's viscosity in high temperature ranges, and most important of all it lowers thermal expansion. (Petzold and Pöschmann 1987).

4.2 Where is it mined? – Origin and production

Borax occurs naturally in a mineral form called "tinkal". It appears in transparent or white, sometimes bluish, greyish or greenish crystals, which are astringent and have a slightly sweet taste. Sites of discovery are the shallow zones of hot springs, and the mud of so-called borax lakes in western Tibet and Cashmere. Borax is found together with Glauber's Salt, rock-salt, gypsum, soda and other minerals. Tibet is commonly known as the source of borax in medieval times. Discoveries of the fumaroles sites in Tuscany near Siena as well as in Turkey, and the extensive discoveries in North America are prospections of the 19th century.

The mineral tinkal, respectively the tinkal soaked earth is refined, and the borax is extracted. Georgius Agricola demonstrates the steps of this refining process on a copper engraving included in his work *De re metallica*.

Figure 8 Refining borax referring to Georgius Agricola.

He refers to the refining of soda, but he confuses it with borax, which he calls chrysokolla. Illustrated is the preparation of the aqueous solution in a vat (A), the boiling and concentration to a supersaturated hot solution in a rectangular pan made from copper (B), the crystallising in a second vat (C), where copper rods are used to support crystallization (D) and the crushing of the crystals in a mortar (E) (Schiffner 1977; see Figure 8)
Most of the borax was traded not in the crushed powdery form, but crystallized, sometimes packed in wooden caskets mixed with animal fat. This way, it reached as far away as Venice.

4.3 Since when is borax known? – Borax in ancient Greek and Arabic sources

As legend has it, the Babylonians and Egyptians used borax four thousand years ago in metallurgy, mummification and medicine. Craftsmen of ancient China used borax in ceramic glazes. First written reference can be found in the Indian text *Arthasastra*, about 300 B.C., "*Borax, which goldsmiths use for welding"* (Wolters 2001).

Unfortunately none of the Greek writers like Theophrastus, Galen or Zosimos mention borax. Only Dioscorides and Pliny the Elder refer to chrysokolla, a "*gold-glue*", which seems to be a mixture of copper ores. In later times, chrysokolla is often confused with borax, because like borax it is used for soldering, and it is an important ingredient for reaction soldering. First reference of borax in ancient Greek times is found in manuscripts of the Late Greek period of the 7th century A.D.

It is assumed that areas north of the Alps had no knowledge of this material in these early times. But it should be kept in mind, that it is not impossible to suggest use of borax in Roman, Carolingian or Viking techniques. However, there is a have a lack of evidence until the present day. Through contact with the Arabic

world during the Christian crusades, and particularly during the occupation of Spain, the Occident came in touch with the profound knowledge of alchemist, astrological and medical matters, and its Greek sources. A study dealing with borax should take a glance at the tractates of the Arabic scholars.
The Islamic chemist Jabir ibn Hayyan (Geber arabicus, 8th c.) mentions *Boraces* as an independent class of minerals next to salts, alums, vitriols and others, but little can be learnt about sources or use. The first definitive reference is found in the works of the Persian physician Al Razi (born and died in Ray, Iran, 865-925). He classified substances into animal, vegetable and mineral matters and subdivided minerals into six categories: Spirits (which sublimate when heated), Bodies (like the metals gold, silver, tin, iron or lead), Stones (like Malachite, pyrites, glass), Salts (rock-salt, potash and other wood ashes), Vitriols (green, yellow, white vitriols) and Boraces (Haage, 2000).

A Coptic Papyrus found at Meshaikh, dating around the 10th century A. D., documents medical prescriptions. It mentions Armenian borax (*"paurak armenei"*) (Travis and Cocks 1984).
Al Hamdani, 942 A.D in Yemen, refers to *burnt tinkar* for purifying gold and silver as well as for soldering, in his work *Kitab al jawharatain al atiquatain* (The precious metals gold and silver). For use in nielloeing he writes *"If they want to inlay (?) silver with this (the niello-compound), they pound it up with borax (tinkar) and water, and fill the place dug out of the silver with this pulverised material. It is allowed to flow like solder in the oven, and it does so."*. Ibn Hawqal (about 978 A.D.) reports on goldsmith's borax from Lake Urmiya (Aserbaidschan), which was used as a flux. He comments: "*it makes substances flow*" (Allan 1979).
Mainly in Spain, Arabic alchemist knowledge was unveiled to European scholars. Results of this interchange of ideas are Arabic scientific works, which became translated into Latin, e.g. *De aluminibus et salibus* (Of alums and salts written by Pseudo-Rhazes). In this document, borates are no longer a class of minerals on their own, but borax is called a salt. The *Liber Sacerdotum* of the 10th century which mentions borax is also a translation of an Arabic text.

4.4 Borax in European references – Soldering and Nielloeing

Not only technical knowledge, but also the material borax itself reached Europe. It is supposed that borax was brought from Mongolia to Venice by Marco Polo in 1295, but borax is mentioned in texts north of the Alps much earlier, which indicates that usage of the material might be possible before the 13th century. A 12th century recipe of the *Mappae Clavicula* deals with borax used for nielloeing: "*Afterwards temper some atincar […] with water, and with this temper the niello and place it where you wish […]. Sprinkle soda [natronum] powder on top, and put it on coals until the niello runs well."* (Smith and Hawthorne 1974). Theophilus' reference is mentioned above. Heraclius writes, "*...and then take the liquor which is called borax..."* (*accipias illum liquorum qui vocatur bures*) (Merrifield 1967).

Later on, borax is quite frequently mentioned, often in connection with preparing niello. The manuscript of Montpellier 1430 reports: "*Take lead, copper as well as silver und fuse the same quantity. Is this done stir with a red-hot charcoal, add sulphur, as much as the amount of the three metals and stir with a red-hot charcoal. Fuse the sulphur and when it is burnt out, pour the mixture to where is clear water, temper with Borax and paint any ornament" ("...et cum boraxa distempera..."*. "*Nimm Blei, Kupfer ebenso Silber und schmilz es zu gleichen Teilen. Ist das geschehen, rühre mit einer glühenden Kohle um, nachher füge Schwefel hinzu, soviel als die drei Metalle an Menge ausmachen und rühre mit einer glühenden Kohle um. Schmelze den Schwefel und wenn er ausgebrannt ist, gieße das Gemenge dahin, wo klares Wasser ist, mische mit Borax und male beliebige Schnörkel."* Rosenberg 1972). Biringuccio 1540 describes borax: "*Borax is of two kinds, natural and artificial. Natural borax is a clear fusible stone of a form like that of sugar candy or rock salt, although Pliny says that it was green, and that it served not only to solder gold but also for painting. It is mined today in Germany. It is easily crushed and pulverized. Artificial borax is made of rock alum and sal ammoniac. Both kinds have the property of facilitating the melting of metals, and they unite and solder whatever they are put on.*" (Smith and Gnudi 1990). 1568 Cellini recommends the use of "*well ground borax from the dredger*" for soldering silver and for soldering with verdigris (Wolters 1986). As well, he uses it in nielloeing: *"Pour your niello which consists of many grains now again in a crucible and it melt in adequate fire with a grain of borax. […] Is this done spread it over the plate, which you engraved, using a spatula made of brass or copper, evenly covering the plate in the height of the back of a knife. Spread a little well ground borax over it, but not too much, […]"* (*Schütte sodann deinen Niello, der jetzt aus vielen Körnern bestehen wird, aufs neue in den Tiegel und lass ihn bei passendem Feuer mit einem Körnchen Borax schmelzen. [...] Ist dies geschehen, so breite ihn [den Niello] mit einer Spatel von Messing oder Kupfer über die Platte aus, in welche du eingegraben hast, und zwar so, dass es sie in der Höhe eines Messerrückens gleichmäßig bedeckt. Nun streue etwas gut gestossenen Borax darüber, aber ja nicht zu viel, [...]* Brinckmann 1978).

After the 16th century, borax vanishes in nielloeing and is replaced by other fluxes like saltpetre, sal ammonic and several mixtures. But in fluxes for fusing and soldering it is still an important ingredient until today. For example, Tomasco Garzoni writes in 1580: *"When it happens that they have to solder, so they do it with low silver or burnt copper with borax…*" (*Wann es sich zutregt/ daß sie auch Löten müssen/ so thun sie*

dasselbige entweder mit geringem Silber/ oder gebranntem Kupffer un Borax… Wolters 1986). Last reference is the goldsmith's treatise *Der künstliche Gold- und Silberarbeiter* from 1708: *"Soldering broken florins. Take ground verdigris, wet put in on the chink, then pour borax on top, let it become red-hot on glow, so the borax will melt and solder together the florin."* (*Zerbrochene Gülden zu löthen. Nimm zerriebenen Grünspan, lege es nass auf den Ritz, dann schütte Borax darauf/ laß auf einer Glut solchen zerglüen/ so zergehet der Borax/ und löthet den Gulden wieder zusammen.* Wolters 1986).

4.5 Borax in European references – Enamelling

In Europe, boron as a compound of enamel glass appears in more recent times, approximately in the 17th century. It is added to the glass compound as a flux in the form of borax. The positive effect of borax for enamelling is first mentioned by Robert Dossie in *Handmaid to the Arts* from 1758. Older references, such as J. G. Kunckel, A. Neri or De Blancourt, do not mention borax in connection with enamel. A manuscript from either De Mayerne, or the enamellist Jean Petitot dating before 1640, mentions "*buros"* or "*bouros"*, which is probably borax (Speel and Bronk 2001). Only in the 19th century, borax was more widely used as an enamel component, facilitated by the better availability, the lower price and the upcoming technology of enamelled iron.

4.6 How did borax reach Europe? Trade and trouble

The borax trade to Europe was via Venice for a long time. Scientists and Craftsmen of Venice knew about the secrets of raffination and guarded it with distrust. Thereby, Venice held the monopoly for a long time and regulated price development by forcing it to a staggering height. The Venetian Borax, "Borax veneta" or "Borrax raffiné", used to be extremely rare in Europe; it was expensive and therefore unattainable and desirable. Johannes Kunckel (1679) deals with this fact when describing a glass mixture by eulogizing borax: "Following composition is much more precious, but equally all the more beautiful…" (*Nachfolgende Composition ist zwar kostbarer, aber auch um so viel desto schöner…* Kunckel 1992). A great quantity of surrogates were invented to replace the desirable material. At the end of the 17th century, the Dutch gained knowledge of the secret of raffination, took over the trade monopoly and held it for almost one hundred years up to 1770, when the French conquered India and derived new tinkal sources. Due to these new sources, and deposits in the New World, the price declined during the 19th century, and borax was available for a broader industrial use.

5. What is meant? - Confusion of the references

When browsing through literature it must be kept in mind that the term borax was not only used to describe borates, but was used as a synonym for flux as well. In addition, several mixtures and surrogates are described. In earlier times it was difficult to differentiate between the different salts, which led to confusion. Mistakes of transcription and misunderstandings of the writers, often because their sources of technical information misled them, caused confusion for hundreds of years.

5.1 Poor Descriptions

Even the initial term, 'borax', was not exact. The medieval translators of the Arabic alchemy texts use the Latin term *borax* variously for a whole group of terms like Hebrew *borith*, Arab *baurach* or *paurak,* Persian *boreck* or Turk *burack,* as well as *bora, baracha burah* or *burraq*. These terms all mean the same: shine, glint, twinkle. It is the description of the appearance of a material, and it does not necessarily refer to borax. The categorization of minerals developed by the physician and philosopher Al Razi (865-925) lists the following under the sub-class of borates: *Tinchar* (*tinkar*), *goldsmith's borax*, *bread borax*, *natron*, *borax of Zarawand* and *buraq al garb*. These listing shows how broad the meaning of the term used to be. *Natron* normally denotes impure natural soda (Latin *nitrum*, *natronum*, or *trona*, Arab *natrun*); it is a mixture of sodium carbonate and bicarbonate. Maybe *bread borax* meant bicarbonate as well. *Goldsmith's borax* might be borax or another borate (possibly the same substance referred to by al Hamdani and Ibn Hawqal), but he describes it as a white efflorescence like the saltpetre found on walls. *Borax of Zarawand* could be this substance as well. Kashani writes about *ranravandi* or *zarvandi*, the name of a village near Nishapur, in his opinion the place of origin. Other references mention a river in Armenia. *Tinchar* seems to be the product of a refined substance, made by boiling *buraq* with *a quail salt and* "*buffalo milk"*. This is why Al Razi calls it artificial borax (Travis and Cocks 1984). Actually, the refining technique of borax requires the use of lime-wash (calcium hydroxide), and that probably misled Al Razi. *Tinchar* originates from the Sanskrit word *tincana* or *tankana,* meaning borax from Tibet and Cashmere. Interesting information is provided by the reference on *buraq al garb*, which is not a mineral substance, but the gum of the willow or acacia tree (the Arab word *algharab* stands for *willow*).

5.2 Mistakes in transcription

The confusion of the European writers, created by mixing up Arabic knowledge with Greek and Roman texts, was already present in the Arabic alchemy. The dictionary of Bar Bahlul of the 10th century mentions "*Chrysokolla, tankar, tanacarau; material, craftsmen use for soldering, tankar"* (Wolters 1986). The term *chrysokolla*, or *auricolla*, *capistrum auri*, *gluten auri* reaches back to the Greek scholars and describes *gold glue*, which is mainly copper oxide used for soldering by reduction, but no salt used as a flux. Confusion was even worse with European authors. The German Georgius Agricola was misled by the text of Pliny and by those who informed him. He confuses soda with chrysokolla and borax. In his text *De natura fossilium* he writes in 1546: *"Natural soda is prospected in the earth or outside of the earth. In the earth you find it hard, dense and more similar to a stone. Of this origin is soda, of which in Venice chrysokolla –as I call the borax- is made. […] The second form of artificial soda is produced of a mined soda even today – in Arabic it is called tinkar. I use to name it, as said before, correctly with the Greek term chrysokolla and not with the Arabic [term] borax."* (*Natürliche Soda findet sich in der Erde oder außerhalb der Erde. In der Erde findet man sie hart, dicht und mehr einem Stein ähnlich. Von dieser Art ist Soda, aus der man in Venedig die Chrysokolla – so nenne ich den Borax – herstellt […] Die zweite Art der künstlichen Soda wird noch heute aus einer Soda, die man bergmännisch gewinnt – arabisch heißt sie Tinkar – hergestellt. Die pflege ich, wie gesagt, mit Chrysokolla, wie es richtig ist, mit dem griechischen Worte zu bezeichnen, als Borax mit dem arabischen…* Wolters 1986).
As well he writes in *Epistola ad Meurerum* (1546) "*Chrysokolla ex nitro confecta Borras"*. His description in *De re metallica* (1556) is well known, which is illustrated by the copper plate of Figure 8: "*chrysokolla, which the Moors called borax"*.

In 1756, Dr. Samuel Johnson characterizes borax in his dictionary with the following words: "*Borax (Borax low Latin), an artificial salt prepared from sal-ammonic, nitre, calcined tartar, sea-salt and alum, dissolved in wine. It is principally used to solder metals and sometimes as an uterine ingredient in medicine*."
Ten years later, Pierre Macquer, professor of chemistry in Paris, has to admit in his Chemical Dictionary "*...We are far from knowing as much concerning borax as is desirable. We are even ignorant of its origin"* (Travis and Cocks 1984).
It took time up to 1808 until the element boron was discovered and the nature of borax was unveiled.

5.3 Surrogates

Apart from inexact or wrong description, several recipes for surrogates called "borax" exist. For example, Andreas Libavius writes in 1597: " The ingenuity of the goldsmith has created several chrysokolla for soldering gold and silver, which they call borax." (*Der Erfindungsgeist der Goldschmiede hat zum Löten von Gold und Silber allerlei Chrysokolla erfunden, die sie als Borax bezeichnen*, Wolters 1986).
J. G. Krünitz (1788) reports of false borax made of alum, saltpetre, soda or tartar. He refers to three methods for separating borax from surrogates: Shape of the crystals, behaviour when exposed to heat, and ability to flow and "liquefy" metals (Krünitz 1788). In addition, Paracelsus and Zedler mention different kinds of surrogate borax (Zedler 1732-1754).

It is remarkable that Heraclius as well as Theophilus uses a more careful definition. Heraclius writes *„accipias illum liquorum qui vocatur bures"* (*„and then take the liquor which is called borax"*), while Theophilus formulates *„accipe gummi, quod vocatur parahas" ("take the resin called borax"*).
Referring to Al Razi, relating willow gum to the borates, an explanation of the term *gummi* might be found in the reference. Did Theophilus refer to a plant gum or Gummi Arabicum as C. R. Dodwell suggests (Dodwell 1961), and called it transmogrified *barabas* in imitation of Arabic terms? Could Theophilus in the beginning of the 12th century be aware of Al Razi's works? Did he refer to a mixture of plant gum and some inorganic flux similar to the numerous surrogates mentioned in the references? Even today, borax is sometimes mixed with traganth (Maryon 1954).
Has such a technique been used in making the niello of the shrine of Vitus?

6. Conclusion

The study of technical manuscripts revealed facts about the knowledge and the use of borax in the medieval Arabic world and Europe until the beginning of the 19th century. Availability of borax north of the Alps in medieval times cannot be proved by literature, due to mistakes of transcription and translation, incorrect descriptions or confusion of terms.
Mention of the term borax in the manuscripts does not inevitably mean that borax was actually used. Therefore, the recipe of the shrine's niello might correspond with the recipe given by Theophilus, even if no content of boron was detected. It is not sure whether Theophilus was speaking of borax or not. As well there is a possibility that the niello contains boron, which could not be detected by analysis.

However, the situation in the matter of the analysed content of boron in the enamel is clear. Borax does not seem to be used for enamel work before the 17th century, but only for refining and soldering techniques as well as for nielloeing. As a conclusion, the sheets of the shrine's lid cannot considered to be authentic. According to our knowledge, they were not produced before the 17th century. This is suggested by the detected contents of boron in the glass, in combination with relatively reliable references.

This case study is not able to sketch the whole situation, but it might throw some light on the topic of borax in early European goldsmith's work. Numerous but unreliable references of that time do exist, and knowledge of the usage of flux in early times is still poor. It is desirable to carry out further analysis referring to the usage of flux. As demonstrated in this work, it may offer information not only concerning the production technique but also regarding dating or authenticity.

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