ISSN 1211–8796

Acta Mus. Moraviae, Sci. geol.
CV (2020): 2, 277–294, 2020

"CRAPAUDINE" (*SCHEENSTIA* TEETH) – THE JEWEL OF KINGS

"CRAPAUDINE" (ZUBY RODU *SCHEENSTIA*) – KLENOT KRÁLŮ

RŮŽENA GREGOROVÁ, MARTIN BOHATÝ, DANA STEHLÍKOVÁ, CHRISTOPHER DUFFIN

There is no other name for the stone that is shrouded in greater ambiguity than the toad stone... Ulisse Aldrovandi (1648)

Abstract

Gregorová, R., Bohatý, M., Stehlíková, D., Duffin, Ch., 2020: "Crapaudine" (*Scheenstia* teeth) – the jewel of Kings. – Acta Musei Moraviae, Scientiae geologicae, 105, 2, 277–294 (with Czech summary).

"Crapaudine"[1] *(Scheenstia teeth) – the jewel of Kings*

Two inconspicuous brown stones in the crown on the reliquary bust of Charlemagne held in the Treasury of Aachen Cathedral are set next to cameos, pearls, precious and semi-precious stones. Rather unusually, they are the button-shaped teeth of a Mesozoic fish called *Scheenstia* (*Lepidotes*) *maximus* (Wagner, 1863). In the Middle Ages, the prevailing belief was that these stones came from the heads of ancient toads and they were attributed magical, protective and healing powers on the basis of sympathetic medicine. The most important of these fabulous properties was the ability to detect and neutralize poisons. This paper presents a short chronological overview of the historical records of toad stones from Antiquity to the emergence of scientific palaeontology as a basis for future study. The principal European palaeontological localities yielding *Scheenstia maximus* (Wagner, 1863) are summarised as possible historical sources for these particular stones. A number of specimens have been studied from museum collections for comparative purposes.

Key words: Scheenstia, teeth, fish, "crapaudine", toad stone, History of Palaeontology, crown, Charlemagne, Charles IV., Aachen.

1. The name "crapaudine" comes from the old French for toad stone.

Růžena Gregorová, Moravian Museum, Department Geology and Paleontology, Zelný trh 6, 659 37 Brno; rgregorova@mzm.cz

Martin Bohatý, Radnická 7, 602 00 Brno; rama.minerals@atlas.cz

Dana Stehlíková, Department of Classical Studies, Faculty of Arts, Masaryk University, Arna Nováka 1, 602 00 Brno; dana.stehlikova@phil.muni.cz

Christopher Duffin, Palaeontology Section, Earth Science Faculty, The Natural History Museum, Cromwell Road, London SW7 5BD, UK and 146 Church Hill Road, Cheam, Sutton, Surrey SM3 8NF, UK; cduffin@blueyonder.co.uk

INTRODUCTION

Some species of fish have spherical or oval teeth developed on their jaws, palate and vomerine bones. This type of dentition is most typical for representatives of the Family Sparidae, but is also found in other extant fish groups, such as the Labridae, Sciaenidae and Anarhichadidae. This form of tooth morphology is typical for so-called durophagous species, in which the teeth are used to crush the hard shells of animals such as crustaceans, sea urchins (echinoids), molluscs and sea lilies (crinoids). These so-called molariform teeth are also distributed amongst fossil species of fish, such as the Mesozoic and Eocene representatives of the orders Lepisosteiformes and Pycnodontiformes. In Tertiary rocks, fossil teeth of this type most commonly belong to representatives of the Family Sparidae (sea breams and porgies) mentioned above. Sediments usually yield isolated teeth whose identification was difficult prior to the emergence of scientific palaeontology. However, the regular shapes of round and oval teeth possessing a smooth shiny surface directly encouraged their use as cabochons in rings, pendants, or other artistic jewels into which the form could be incorporated with very little working. During the Middle Ages, the belief prevailed that these stones came from the heads of ancient toads; they were ascribed magical, protective and healing powers on the basis of sympathetic medicine, the most important of which was the ability to detect and neutralize poison. Toads are known to secrete toxins from warty dermal structures on the body, especially from the parotid glands which are located behind the head. The principle of sympathetic magic states that things that have a shared resemblance also have a functional connection. Such so-called toad stones, set in gold and silver rings are listed as treasures in the inventories of noblemen such as Duke John of Berry (1340–1416), Philip the Good (Duke of Burgundy; 1396–1467) or Louis I, Duke of Anjou (1339–1384) (Duffin 2010). Items containing toad stones (Bauer, Haupt 1976, Bodenstein 1919, Zimerman 1889) are also listed in the inventories of the imperial treasury of the Viennese court. Museum collections and royal treasuries preserve many items of material culture pertaining to these special beliefs, especially rings mounted with button-shaped teeth. The Royal Treasury of the National Museum in Copenhagen houses four rings with toad stones dating from the 16th to 17th century (Lindahl 2003, Gundestrup 1991). A relatively large number of these artifacts is preserved in the Ashmolean Museum in Oxford and the Victoria and Albert Museum in London (Dalton 1912). Toad stones also formed part of a treasure trove of jewellery and precious stones dating to the late 16th and early 17th centuries, discovered in 1912 in London during excavation work. The wooden box containing the hoard held more than 400 pieces of jewellery from the reign of Queen Elizabeth I (1533–1603) and King James I (1566–1625). The treasure included rings, brooches and chains, together with isolated precious stones, including toad stones, which clearly formed part of the stock intended to be used in jewellery production (Duffin 2008).

The impetus for this article was the identification of two button-shaped teeth of the fossil fish *Scheenstia maximus* (Wagner, 1863) on the imperial crown which adorns the reliquary bust of the Frankish king and the first Roman emperor of the early Middle Ages, Charlemagne († 814). According to historians, Charles IV was crowned king of the Holy Roman Empire with this crown in June 1349. The crown, together with the bust, is one of the most valuable items in the treasury of the chapter house in Aachen. However, the provenance and date of manufacture of the crown is still entwined with ambiguities. Opinions on the origin of the crown were, for example, analyzed in detail by the German historian Albert Huyskens (1938) who considered that it might even have belonged to Charlemagne himself. Cherry (1992) states that the crown was one of the gifts of Richard of Cornwall (1209–1272), who was crowned King of the Romans in the Imperial Cathedral in 1257. Grimme (1972), Poche (1982) and Bobková (2003) believe that Charles IV had the crown made for his imperial coronation, given that he did not yet have an imperial insignia at his disposal. Other authors admit the idea that the imperial crown was part of the domestic treasure of Charles IV so that Charles is then credited only with the addition of a single decorated arch or hoop passing from front to back, with a cross attached to the front (Poche 1965, Pleticha 1989, Žemlička 2005). Žemlička (2005) also raises the interesting hypothesis that this could be the original crown of Wenceslas II (1271–1305), which then became the property of Charles IV. Other opinions on the origin of the crown are also summarized in the dissertation of Lucie Kodišová (2019).

The imperial crown comprises a single-piece gilded and jewelled headband, decorated with four large jewelled lilies (fleur-de-lys) each separated from the other by one of four smaller stylised lilies, each with a single leaf-like petal. From a gemmological point of view, the crown has yet to be elaborated in detail. In the literature we find identifications for only some of the stones which were used in the decoration, such as amethysts, rubies, sapphires, emeralds, pearls and cameos (Poche 1965). The use of fossil teeth belonging to *Scheenstia maximus* to accompany the precious stones in the external ornament of the crown is absolutely unique and goes beyond the traditional use of precious stones in the decoration of such an important medieval insignia as the royal crown (Gregorová and Duffin, 2019). Similar stones could be found neither among the other works of art exhibited at the Imperial Treasury, where the crown is stored, nor in the Treasury of St. Vitus Cathedral in Prague, nor in the Imperial Treasuries in Vienna and Munich.

We present below a description of the teeth decorating the crown and identify the most important diagnostic features allowing us to allocate them to the species *Scheenstia maximus* (Wagner, 1863). Comparative material was also studied in order to judge any variability in shape, surface structure and colour of the teeth. In an effort to identify potential deposits from which medieval and modern merchants or goldsmiths might have obtained the supposed toad stones, we also present an overview of deposits containing teeth of the species *Scheenstia maximus*. We also present a basic chronological overview of historical records of toad stones from Antiquity to the emergence of scientific palaeontology as an introductory basis for more detailed study.

MATERIAL AND METHODS

1. Imperial crown: weight approximately 2000 g, circumference 67 cm, diameter 21 cm, height 26.5 cm, held in the Aachen Cathedral Treasury (*Aachener Domschatzkammer*), Germany.
2. A collection of 158 specimens of the teeth of *Scheenstia maximus* from the collections of the paleontological department of the Natural History Museum in Vienna (NHMW); most specimens come from the mineralogical cabinet of the imperial collection (K.K. Mineralien Kabinett). In most cases, they are labelled *Sphaerodus gigas* Agassiz, 1833 – one of the junior synonyms of *Scheenstia maximus*. In two samples, the original labels are labelled "Glossopetréen" (tonguestones) and "Buffonitten" (toad stones). The teeth come from the localities of Štramberk (17 specimens), Mikulov (70 specimens), Falkenstein (31 specimens), Trento (24 specimens), and South Tyrol (8 specimens). The collection also includes a set of six teeth without locality data from the oldest imperial collection (Ortwin Schultz – oral communication), amongst which, in addition to the teeth of *Scheenstia maximus*, there were specimens belonging to Tertiary sparids (? *Pagrus*).
3. A set of six specimens of button-shaped teeth belonging to both the Mesozoic genus *Scheenstia* (4 specimens) and representatives of the Sparidae (*Pagrus*, 2 specimens) from the Cabinet of curiosities of Strahov Monastery, (Gregorová *et al.*, publication in preparation).
4. Five specimens of sparid teeth from Děvínská Nová Ves, 2 specimens of *Scheenstia maximus* from Mikulov, 2 specimens of *Scheenstia maximus* from Štramberk from the collections of the Moravian Museum.

The material was studied under an Olympus SZX10 microscope and photographed with a Canon EOS1100D and Nikon D90 digital cameras. The reference material was studied under an electron microscope. The systematic classification of teeth into the species *Scheenstia maximus* is based on their relatively large size, as other species belonging to the genus are significantly smaller. The diameter of the teeth of *Scheenstia maximus* is around 10 mm. The terminology of the tooth structure follows that of Sasagawa *et al.* (2009).

TEETH OF *SCHEENSTIA MAXIMUS* ON THE IMPERIAL CROWN: IDENTIFICATION AND DESCRIPTION

The fossil teeth are set symmetrically in a significant place – at the tops of the lateral leaves on the posterior (occipital) side of the crown (Fig. 1). They are each held in place by four metal clasps. Both specimens are round in outline with a diameter of 15 mm, are light brown to cinnamon in colour with a matte sheen and a smooth surface. The tooth mounted in the right leaf of the crown (from the point of view of the occipital side) has distinct dark spots on the surface caused by the presence of iron or manganese oxides (Fig. 2). The left-hand specimen is the more convex and has a regular whitish stripe at the base (Fig. 3). At first glance, both teeth look like cabochons made of chalcedony, aragonite or degraded pearls, which is probably why their true nature has long escaped the attention of gemmologists and art historians. The essential diagnostic features of the teeth on the crown are their regular round shape, smooth surface and their brownish colour with a matte opalescent gloss. Precious stones on medieval works of art generally show rather rough irregular workmanship, as a lot of effort was invested in preserving as much of the precious material as possible and the production of regular round shapes was technically demanding. On the toad stone specimen from the left posterior side of the crown, typical tooth structure can be clearly observed, in which the finely wrinkled edge of the enameloid tooth covering (acrodin) is preserved, passing downwards into the histologically different ganoin tissue (collar enameloid), (Fig. 4).

Fig. 1. The back of the Aachen crown with teeth at the top of the stylised lily leaf. Photo Růžena Gregorová. © Aachener Domschatzkammer.

Obr. 1. Týlní (zadní) strana cášské koruny s adjustovanými fosilními zuby ve vrcholech liliových lístků. Foto Růžena Gregorová. © Aachener Domschatzkammer.

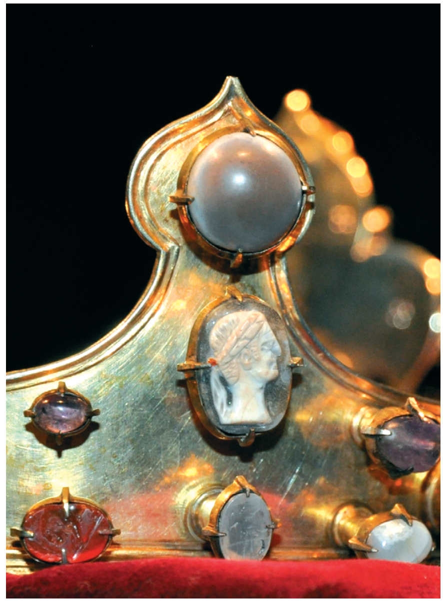
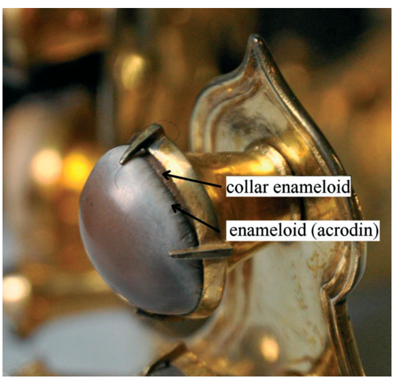


Fig. 2. Detail of the right stylised lily leaf with a toad stone (tooth), diameter 15 mm. Photo Růžena Gregorová. © Aachener Domschatzkammer.

Obr. 2. Detail pravého liliového lístku s ropuším kamenem (zubem), průměr 15 mm. Foto Růžena Gregorová. © Aachener Domschatzkammer.

Fig. 3. Detail of the left lily leaf with toad stone (tooth), diameter 15 mm. Photo Růžena Gregorová. © Aachener Domschatzkammer.

Obr. 3. Detail levého liliového lístku s ropuším kamenem (zubem), průměr 15 mm. Foto Růžena Gregorová. © Aachener Domschatzkammer.



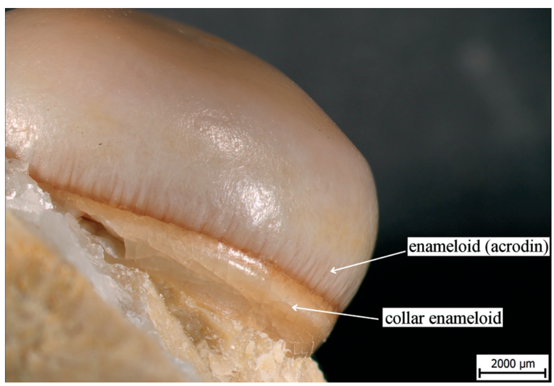


Fig. 4. Detail of the left toad stone (tooth) showing the enameloid structure (acrodin) and collar enameloid. Photo Růžena Gregorová. © Aachener Domschatzkammer.

Obr. 4. Detail levého ropušího kamene (zubu) s viditelnou strukturou enameloidu (akrodin) a okrajem „enameloidního límce“. Foto Růžena Gregorová. © Aachener Domschatzkammer.

Fig. 5. *Scheenstia maximus*, wrinkled structure of enameloid (acrodin) and collar enameloid, Mikulov-Turold. Foto Růžena Gregorová.

Obr. 5. *Scheenstia maximus*, zvrásněná struktura enameloidu (acrodin) a „enameloidního límce“, Mikulov-Turold. Foto Růžena Gregorová.

This structure can be compared with a specimen from the locality Mikulov (Turold), (Fig. 5). From close examination of this junction, it can be concluded that the teeth had not been surface-treated in any way. The enameloid (acrodin) has a fibrous structure comprising intersecting bundles, which can clearly be demonstrated in examples of isolated teeth from Štramberk (Fig. 6). A vertical section through a tooth from Mikulov shows the boundary between the enameloid (acrodin) and the underlying dentine. This is a functional tooth (see below; Fig. 7).

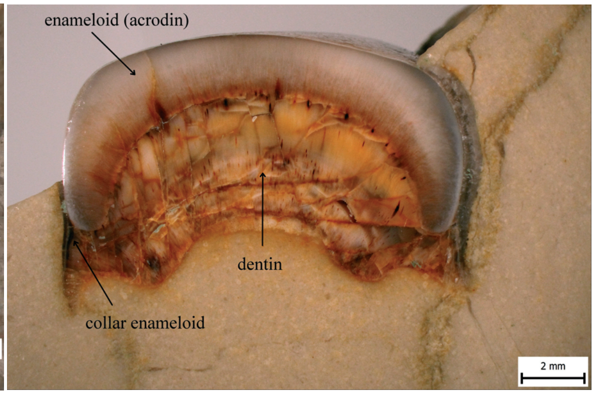


Fig. 6. *Scheenstia maximus*, fibrous structure of enameloid (acrodin) arranged in various directions, diameter 15 mm, Štramberk. Foto Růžena Gregorová.

Obr. 6. *Scheenstia maximus*, fibrózní struktura enameloidu (akrodin) uspořádaná v různých směrech, průměr 15 mm, Štramberk. Foto Růžena Gregorová.

Fig. 7. Vertical section of *Scheenstia maximus* tooth, Mikulov, Turold, NHMW, 2019/0147/0001. Photo Růžena Gregorová.

Obr. 7. Příčný řez zubem *Scheenstia maximus*, Mikulov, Turold, NHMW, 2019/0147/000,1. Foto Růžena Gregorová).

ORIGIN OF THE TOAD STONE – *SCHEENSTIA* FOSSILS IN GENERAL

The genus *Scheenstia* López-Arbarello and Sferco, 2011 includes about ten species of fish and belongs to the order Lepisosteiformes (López-Arbarello 2012), a group which includes modern gars. Originally, some members of the genus *Scheenstia* were included in the genus *Lepidotes* Agassiz, 1832. Until recently, *Lepidotes* was a basket genus gathering together tens of species ranging from the Triassic to the Cretaceous, but after taxonomic revision, this genus is now restricted to the Early Jurassic. Most species of *Scheenstia* are known mainly from the Jurassic and Cretaceous of Europe the most typical of which are the species *Scheenstia mantelli* (Agassiz, 1833), first described from the English county of Sussex, *Scheenstia laevis* (Agassiz, 1837) from the Upper Kimmeridgian of the historically important French locality of Cerin, and *Scheenstia maximus* from the Tithonian of important German deposits at Solnhofen, Kelheim, Eichstätt and Langenaltheim. This Mesozoic genus is characterized by a spindle-shaped body, externally homocercal tail and large robust shiny ganoid scales. The largest and most impressive species of the genus is the aforementioned *Scheenstia maximus*. The neotype of the species is a complete specimen from Langenaltheim, with a total body length of almost 2 m (SMF P. 2386; López-Arbarello 2012) (Fig. 8). An important feature of this genus is its special dentition. The teeth

Fig. 8. Detail of the head of *Scheenstia maximus* with button-like teeth, Langenaltheim, SMF P. 2386, Photo Růžena Gregorová.

Obr. 8. Detail hlavy *Scheenstia maximus*, s knoflíkovitými zuby, Langenaltheim, SMF P. 2386. Foto Růžena Gregorová.

have a hemispherical, button shape. In the genus *Scheenstia*, the teeth on the lower jaw are arranged in a single row on the dentary bone and in several rows on the fused adjacent prearticular and coronoid bones, which are situated lingually. The bones of the palate (dermopalatine and vomer) possess durophagous (button-shaped) teeth on each side (Leuzinger *et al.* 2020). It was these palatine button-shaped tooth types, plus those from the prearticular coronoid (lower jaw) that were historically considered to be toad stones. A specialised type of tooth replacement, unique amongst the vertebrates, has been described for members of the genus *Scheenstia*. This involves the rotation of their acrodin crown through 180°, an event which occurs in bony crypts in the jaw bone (Leuzinger *et al.* 2020). This is probably why these teeth are often found as isolated structures in the sediment. It is even possible to tell from these isolated teeth whether a particular specimen is a functional tooth or a tooth from a non-functional position. The latter has only an acrodin layer, while a functional tooth consists of both acrodin and dentine. Fossil remains belonging to the genus *Scheenstia* are widespread mainly in platform deposits of Europe, including those of the Swabian Jura (Schwäbische Alb) and the Franconian Jura (Fränkische Alb). In the Swabian Jurassic region, these teeth have been recorded from Schnaitheim under the name *Lepidotus maximus* Wagn. (Zittel 1870). Famous fossil sites such as the aforementioned Langenaltheim, Kelheim, Eichstätt and Solnhofen are located in the Frankish Jura Mountains. Another area where *Scheenstia* fossil remains occur is the Jura Mountains, which form a 300 km long arc stretching from the northwestern part of Switzerland to eastern France. In the Swiss section of the Jura Mountains teeth of *Scheenstia* have been recorded from Thayngen (Peyer 1954), Courtedoux (Leuzinger *et al.* 2020) and the surroundings of Neuchâtel (Pictet and Jaccard 1860), whilst in the French region they have been reported from the aforementioned locality, Cerin. Upper Jurassic and Lower Cretaceous sediments yielding *Scheenstia* teeth are also abundant in the Anglo-Paris Basin. On the French side, Boulogne-sur-Mer (Cuny *et al.* 1991), Cordebugle (Buffetaut *et al.*, 1985) and Canjuers (Peyer *et al.*, 2014) are worthy of mention. Boulogne-sur-Mer, cited above, lies in the so-called Boulonnais, a coastal area of northern France which is linked structurally across the English Channel with the Wealden area by means of the Weald-Artois anticline. Here, too, there are a number of paleontological sites yielding isolated teeth of the genus *Scheenstia* (Etheridge and Willett 1889). The Natural History Museum in London has a rich historical collection of these teeth from both Upper Jurassic and Lower Cretaceous localities, including sites exposing the Kimmeridge Clay in Wiltshire and at Shotover (Oxfordshire), the Oxfordian at Upware (Cambridgeshire), and the Lower Cretaceous of Tilgate Forest, Sussex, and Potton (Bedfordshire). Finds are also known from the Isle of Purbeck (Swanage).

Another important region for *Scheenstia maximus* is the wide area around Trento in the Southern Alps (Zittel 1870, Bassani 1885, D'Erasmo 1922, 1927). Thanks to a detailed catalogue of Mesozoic vertebrates and their provenance in the Tre Venezie region, based on material stored in museum and university collections throughout northern Italy (Sirna *et al.* 1994), ten sites recording the occurrence of *Scheenstia maximus* have been documented between Trento and Verona. The authors note that, in the case of the genus *Scheenstia* (which they refer to under the older synonym *Lepidotes*) the specimens mostly comprise isolated teeth. Zittel (1870) noted that the quarry workers who broke open the rocks and found these teeth called them "occhi" (eyes).

Rich collections of isolated teeth of *Scheenstia maximus* are also recorded from the Carpathian region, from Kimmeridgian to Berriasian rocks exposed at two localities in the so-called Waschberg-Ždánice unit: Mikulov in Moravia and Falkenstein in Lower Austria (Schneider *et al.* 2013). From a historical point of view, it is worth mentioning that some finds from the vicinity of Mikulov were donated to the collections of the Vienna Museum in the middle of the 19th century by Joseph Popellack, the court architect of Liechtenstein at Valtice Chateau. Kotouč hill in Štramberk, which connects to the Waschberg-Ždánská zone, has yielded button-shaped molariform teeth first described by Remeš (1897) under another synonym of *Scheenstia*, *Sphaerodus gigas* Agassiz, 1933. Blaschke (1911) later allocated these teeth to *Lepidotes maximus* Wagner, 1863 and, in addition to Štramberk, mentions the already mentioned localities of Kelheim, the Southern Alps, Sicily, Switzerland and the Carpathians. From Romania, Blaschke also cites specimens from the Upper Jurassic of Gyilkoskö (Ghilcoș) in the Hășmaș Mountains. Further material includes recently recorded specimens from the Kimmeridgian of the Fagul Oltului valley in the Eastern Carpathians of Romania (Lazar *et al.* 2010). From the Pieniny Klippen Belt, Zittel (1870) and Blaschke (1911) both report teeth of *Scheenstia maximus* from a site at Rogoźnik in southern Poland.

One area worthy of further study is the analysis of colour variability in the teeth of *Scheenstia*. This could potentially help in determining the historical provenance of isolated teeth mounted on various artifacts, especially the imperial crown. The colour range of *Scheenstia maximus* teeth from individual localities varies from beige, cinnamon brown, dark brown through to grey and varies from locality to locality depending on the degree of diagenetic alteration. A relatively large range of colour variation is present in the collection of teeth from the Austrian locality of Falkenstein. The collection contains uniformly beige teeth plus multi-coloured, speckled examples exhibiting different shades of beige, mixed with whitish, grey and brown variations. Specimens from Pálavské vrchy in the vicinity of Mikulov and the German locality of Eichstätt are mostly light beige in colour. Specimens from the Trento in Italy are brownish with a slight hint of light cinnamon colour and an even lighter margin toward the base; several teeth are a very light porcelain colour. Material from English localities also show a large colour range, amongst which are spotted examples in shades of white, cinnamon and grey, as well as specimens which are predominantly light cinnamon in colour. Teeth from Štramberk are the most different from the others, being medium grey and often exhibiting a high gloss. The teeth mounted on the Imperial crown, based on a preliminary study of the colour variability of the material available to us, best match the colour of specimens collected from the vicinity of Trento in Italy, or those from the Oxford area in England.

EUROPEAN TOAD STONES VERSUS OLDEST HISTORICAL RECORDS

Written historical sources have been consulted in an effort to identify possible sources of toad stones exploited in the past. Important information is furnished by the Italian scholar Aldrovandi who, in his entry for toad stones (bufonites) in his *Musaeum metallicum* (1648), describes the places where these precious stones intended for mounting in jewellery were found: "The rocks are smashed with an iron hammer, some fragments fall off like plaster on the wall, and these stones appear on them like knots on wood and shine like stars. These are then collected and transported to Spain, Poland and other countries. We also know that they appear in some places in Germany today". In the case of Gaul (France), Boulogne-sur-Mer in Normandy, on the shores of the Atlantic Ocean, is a potential locality where these teeth might have been found; they are still being collected there today. This example of a possible historical source of prized bufonites, is supported by the fact that obtaining the stones did not require a great deal of effort – they are commonly washed out of the clays exposed in the cliff face. In the case of Germany, the Upper Jurassic localities around Solnhofen (Franconian Jurassic) are potential candidates for yielding historical material. A holomorphic specimen of *Scheenstia maximus*, including jaws armed with large button-shaped teeth was discovered here. Active quarrying of the Solnhofen limestones dates back to the 2nd century AD (Arratia *et al.* 2015) so the area cannot be ruled out as a potential source of toad stones. In general, however, there are currently no isolated teeth recorded from the Franconian region (oral communications by Martin Röper and Martin Ebert).

A STONE WITH A LONG HISTORY

Scheenstia's hard, button-like, shiny teeth, together with fossil sharks' teeth, also attracted the attention of our prehistoric ancestors and have been described, for example, from a Bronze Age burial ground in Wiltshire (Oakley 1975).

Pliny the Elder (23–79) in his famous *Naturalis Historia* (37, 149) lists three varieties of the stone "batrachites" (from the Greek "βατραχος", "batrachos" – toad), among the precious stones. Similar to a frog in colour, they were reported as coming from the area of Koptos (now Qift, Egypt). According to the description, the first variety has a frog-like colour, the second is veined and the third is a mixture of red and black. Coptos, located on the banks of the Nile and near the Red Sea, has long been an important trading centre, from where caravans transported goods through the Le Ouadi Hammamat valley (the dry arm of the Nile) to the Red Sea. There were also a large number of quarries where limestone and serpentinites were mined and exported (Bernard 1977, Harrell and Storemyr 2009). Some species of serpentinites correspond to the description of Pliny's "lapis batrachites" and some authors consider serpentinite from the Wadi Umm Esh valley to be his (first and second variety) batrachites (Harrell 2012). The third variety could come from blocks of speckled red and black stone, which could be altered forms of porphyry occurring in the Mons Porphyrites area (today Jabal Abu Dukhkhan), (Peacock and Maxfield 2007). However, these rock varieties, as the description shows, have nothing to do with toad stones – the teeth of fossil fish. The writings of scholars from the Middle Ages are dominated by the view that these stones are formed in the heads of toads or, in one case frogs. The latter concept is restricted to the *Kyranides*, a magical-medical compilation concerning the occult forces of plants, animals and stones, dating from the 2nd to the 4th century. In the *Kyranides*, however, no specific name is used for the stone formed in the toad's head. Medieval authors of encyclopaedias and scientific treatises during the 13th century, such as ARNOLD SAXO, BARTOLOMAEUS ANGLICUS, THOMAS DE CANTIMPRÉ, VINCENTIUS BELLOVACENSIS and ALBERTUS MAGNUS mention the stone under a variety of names – borax, botrax, nose, noset, nuse or crapadina. Basic historical overviews are given by FORBES (1972) and DUFFIN (2008, 2010), and a more detailed analysis of the sources is planned (STEHLÍKOVÁ *et al.*, in preparation). Medieval authors agree on the curative effects the stone was able to exercise against poisons or reptile bites, and the means by which it was harvested from the head of a still-living toad. Apart from colour and the alexipharmic effects credited to it, we do not find descriptions of toad stones in these writings. We can only conclude from them that they were small because they formed in the heads of toads. In the 14th century, the toad stone also made an appearance in Bohemian literature – in the Glossary of *Magister Bartholomaeus de Solencia dictus Claretus* or BARTHOLOMEW OF CHLUMEC. Also known as MASTER KLARET (1320–1370), this gentleman was canon of St. Vitus Cathedral and master of the University of Prague. He mentions the toad stone under the name borax and crapaudin. A description of the stone and its healing effects is recorded only in the first Czech lapidary, part of the so-called Vodňany Codex, dated to around 1410. An unknown translator and compiler describes a total of 66 stones which were known at the time and used in medicine. The toad stone can be found here under two names, botrax and nadar. The lapidary of the Vodňany codex was reproduced by geologist JAN KREJČÍ (1859) and more than 100 years later by mineralogist KAREL TUČEK (1983).

During the Renaissance there was a huge upsurge of interest in scientific knowledge. On the one hand, the ideas from medieval tradition were still popular, having held sway for a long period of time. On the other hand, some authors began to question medieval myths and started to search for the true origin of toadstones. The fabled method of obtaining a stone from the heads of old toads, in accordance with medieval ideas, forms the subject of an illustration in the old herbal and encyclopaedia of nature and medicine, the HORTUS SANITATIS, which was published anonymously in 1491 (Fig. 9).

Fig. 9. Obtaining a stone from the head of a toad (HORTUS SANITATIS 1491).
Obr. 9. Zobrazení získávání kamene z hlavy ropuchy (HORTUS SANITATIS 1491).

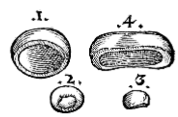


Fig. 10. The very first illustration of toad stones (GESSNER 1565).
Obr. 10. Vůbec první ilustrace ropuších kamenů (GESSNER 1565).

The Zurich physician KONRAD GESSNER (1516–1565) was the first to make a significant contribution to understanding the true nature of toad stones. In his 1565 work *De rerum fossilium, lapidum et gemmarum*, we find their very first pictorial depiction under the names batrachitae or crapodinae (Fig. 10). Thanks to these images, palaeontologists were able to assign them with some confidence to the teeth of fossil fishes belonging to the genus *Scheenstia* or to pycnodont and sparid fishes, as cited above. GESSNER does not mention the site from which these stones were collected, and neither does he comment on their origin. Later, the Italian naturalist, ULISSE ALDROVANDI (1522–1605), in his work, *Musaeum metallicum* (1648), aptly characterizes the wide controversy then present amongst contemporary scientists and mentions a number of authors who deal with this stone. ALDROVANDI tries to organize the views presented to date and attaches his own interpretations to them. The number of names in use for the toad stone was growing; the most commonly used were bufonites and lapis bufonis. According to ALDROVANDI, others included vernacular names such as "Krötenstein" (German: "die Kröte" – toad), and "pietra del rospo" ("rospo" in Italian – toad), plus also Pliny's name batrachites (but with a new meaning), and the analogous name rubetites – both names are derived from the words for toad (Greek batrachos, Latin rubeta). ALDROVANDI first comments on a picture of a toad-like stone and suggests that heavily mineralized water might cause the animal to become petrified. It could be argued that these are amongst the earliest, more realistic (to modern eyes) ideas about the formation of fossils. However, the author continues: "Likewise, a stone should be described as bufonites, which would be turned into the form of a toad by playful nature. Nature is admirable because it creates stones that reflect the various shapes of living beings from such a solid. Such a character was also a stone composed of sandy matter, which was accidentally found in the mountains near Bologna." Here ALDROVANDI refers to the then widespread notion that fossils were created as "sports of nature" (*lusus naturae*) by a special stone-forming "lapidifying juice" and imitating force of nature (*vis plastica*, *vis lapidifica*) (Fig. 11). According to the picture which he provides, both species can be interpreted as concretions. These often arise during the diagenetic processes which take place in sediments, sometimes forming structures which, with a bit of imagination, resemble the shapes of animals. A typical example is the so-called "cicvars", precipitated lumps formed in loess clays. Another type of bufonite, as the description and pictures show, is the button-shaped fish tooth. ALDROVANDI used an illustration by KONRAD GESSNER and added eight depictions of his own, including three specimens with bevelled shapes. Four specimens from Aldrovandi's illustration have survived to the present day in the Museo di Palazzo Poggi in Bologna. They are labelled as *Coleodus* sp. and *Lepidotes gigas* (AGASSIZ, 1832) from Lower Cretaceous of France (with a question mark) (Fig. 12).

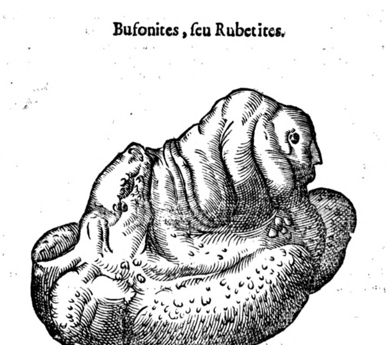


Fig. 11. Toad stone (fossilized toad) made by the creative force of the Earth (*vis plastica*), (ALDROVANDI, 1648).

Obr. 11. Ropuší kámen (zkamenělá ropucha) vzniklý tvořivou silou Země (*vis plastica*), (ALDROVANDI, 1648).

Fig. 12. Aldrovandi's "batrachites" and "bufonites", Museo di Palazzo Poggi, Bologna. © Universita di Bologna-Sistema Museale di Ateneo.

Obr. 12. Aldrovandiho "batrachites" a "bufonites", Museo di Palazzo Poggi, Bologna. © Universita di Bologna-Sistema Museale di Ateneo.

Renaissance authors basically settled down to the general conclusion that there were several types of toad stone, amongst which was one that was found in the rocks and in the ground and to which they attached mineral origin. Paradoxically, it is these stones that are, according to the illustrations and descriptions, the teeth of fossil fish. The work of the Neapolitan pharmacist Ferrante Imperato (1550–1625), *Dell'Historia Naturale* (1599), in which he illustrates the contents of his own cabinet of curiosities in Palazzo Gravina also plays an important role in a developing understanding of the origin of toad stones. Imperato was one of the first to correctly understand the process of fossil formation with the help of experiments. In his work he depicts some "pietra di rospo" toad stones enclosed in matrix and ascribes a mineral origin to them (Fig. 13). However, he also mentions the effects of stones in folk medicine, such as providing a remedy for fever, kidney stones and as an antidote to poisons. The personal physician of Rudolph II (1552–1612), Anselm Boëtius De Boodt (1550–1632) even tested empirically the extraction of a stone from a toad's head using a red scarf, as recommended by other authors: "I remember catching an old toad as a boy and putting it on a red scarf to get such a stone, because only on such a scarf does a toad give a stone. But even though I watched her all night, she did not release any stone." Based on this experience, De Boodt considered the legend of such stone formation to be a fraud (De Boodt 1609).

Fig. 13. Ilustration of the toad stones "pietra di rospo" in rock matrix (Imperato 1599).
Obr. 13. Ilustrace ropuších kamenů "pietra di rospo" v hornině (Imperato 1599).

At this point, it should be noted that as early as the second half of the 17th century, two personalities, independently of each other, Christopher Merrett (1667) and Agostino Scilla (1670) compared toad stones with fish teeth they had encountered from their own observations in nature. Since these scholars belonged to the pre-Darwinian period, they had no idea of evolution and extinction and had no idea that they could be the teeth of extinct fish. The English naturalist and physician scientist Christopher Merrett (1614/15–1695), a Fellow of both the Royal Society of London and the Royal College of Physicians, likens bufonites to the molariform teeth of the extant common Atlantic wolffish *Anarhichas lupus* Linnaeus, 1758, adding: "the goldsmiths, greatly admiring, have acknowledged that these teeth are the true toad stones that they sell individually".

The Atlantic wolffish is a large marine fish of the order Perciformes whose body length reaches up to 1.5 m, and which occurs in the Northern Atlantic Ocean (Fig. 14).

Fig. 14. *Anarhichas lupus* LINNAEUS, 1758, view on the upper jaws and floor. © Esterházy Privatstiftung, Forchtenstein Castle – Treasure Chamber. Photo Růžena Gregorová.
Obr. 14. *Anarhichas lupus* LINNAEUS, 1758, pohled na horní čelisti a patro. © Esterházy Privatstiftung, hrad Forchtenstein – pokladnice. Photo Růžena Gregorová.

Another author, the Italian scientist and painter AGOSTINO SCILLA (1629–1700), is an important figure in the history of palaeontology. In 1670 he published a book in Naples, *La vana speculazione disingannata dal senso*, in which he deals with the origin of fossils. The volume was actually written in response to the Maltese doctor, Dr. CARLO, who tried to convince SCILLA that fossils were created in the earth through spontaneous generation and had never been parts of animals. SCILLA also focuses on the button-shaped fossil teeth, which were popularly called "snakes' eyes" ("occhi di serpe") in Sicily and Malta, and illustrates that they are comparable to the teeth of the sparid fish "sargo" – *Diplodus sargus* (LINNAEUS, 1758), "orata" – *Sparus aurata* (LINNAEUS, 1758) or "dentice" – *Dentex dentex* (LINNAEUS, 1758), (Fig. 15). SCILLA explains the different coloration of teeth from Malta and the Sicilian locality of Corleone by reference to different environments of fossilization.

It was not until the 18th century that the first suggestions were made concerning the different distribution of continents, the existence of now extinct species of organisms and ancient seas. ANTOINE DE JUSSIEU (1686–1758), the uncle of the famous botanist ANTOINE LAURENT DE JUSSIEU (1748–1836), considers "crapaudines" to be the fossil teeth of the "grondeur" from the Brazilian coast (DE JUSSIEU 1723). This probably refers to the species *Pogonias cromis* (LINNAEUS, 1766) belonging to the family Sciaenidae, which lives in the coastal waters of the Atlantic Ocean from the Gulf of Maine through Florida to Argentina. He also compares them to teeth of the "dorade" (*Sparus aurata* LINNAEUS, 1758) or Gilt-head bream. DE JUSSIEU explains the presence of fossil remains not represented in modern seas by changes in the environment and the positions of the continents.

Fig. 15. Illustration of jaws of sparid species and isolated fossil teeth from Malta (Scilla 1670).

Obr. 15. Ilustrace čelistí sparidních druhů a izolované fosilní zuby z Malty (Scilla 1670).

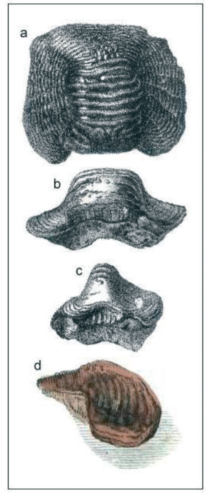


Fig. 16. *Buffonites undulatus* (a, b) and *Buffonites knorrii* Sternberg, 1829 (c, d).

Obr. 16. *Buffonites undulatus* (a, b) a *Buffonites knorrii* Sternberg, 1829 (c, d).

Similarly, Pierre Barrére (1690–1755) dealt with the origin and formation of "pierres figurées", i.e. stones with a regular shape and somewhat resembling that of certain living things (Barrére 1746). He searched for the origin of fossil molluscs from ancient oceans and considered "crapaudines" to be teeth similar to those of the sparid fish "sinagris de rondelet", or *Dentex dentex* (Linnaeus, 1758).

Andreas Xaverius Stütz (1747–1806), director of the Imperial Mineralogical Cabinet in Vienna, describes black "Krottensteine" from the Lower Austrian region around Maissen as the teeth of the modern wolffish, *Anarhichas lupus* Linnaeus, 1758 (Stütz 1807). They are probably button-shaped sparid teeth from the Miocene. Toad stones are interpreted in a similar way by the English surgeon, palaeontologist and one of the founding members of the Geological Society of London James Parkinson (1755–1824) (Parkinson 1830). In general, up to the beginning of the 19th century, the button-shaped molariform teeth of various fossil fish (*Ptychodus*, *Lepidotes*, and members of the Pycnodontiformes) were referred to as bufonites (e.g. Brignon 2019). It should be noted that palaeontologists at this time understood that many fossils could not be assigned to recent taxa and were beginning to describe and establish new fossil genera and species. Kaspar Maria von Sternberg (1761–1838) even used Bufonites as a generic name for *B. undulatus* and *B. knorrii* for fish now allocated to the genus *Ptychodus* from the Czech Cretaceous Basin (Brignon 2015), (Fig. 16). This, perhaps the longest history of a single fossil, ends in 1832 with the Swiss ichthyologist, Louis Agassiz (1807–1873), who raised the extinct genus *Lepidotes*, which was sub-divided into numerous species mostly during the 19th and 20th century. Recently, taxonomic revisionary work has decreased the number of valid species, and some of the original species have been assigned to new genera including *Scheenstia* López-Arbarello and Sferco, 2011, (López-Arbarello 2012).

SUMMARY

The provenance and date of origin of the imperial crown decorating the reliquary bust of Charlemagne in the Treasury of the Cathedral of the Virgin Mary in Aachen is still shrouded in ambiguity. The two button-shaped teeth belonging to the fossil fish *Scheenstia maximus* and identified here for the first time on the occipital part of the crown are absolutely unique occurrences on an item of such important medieval insignia, and their setting on the crown goes beyond the traditional use of precious stones in medieval works of art. A preliminary analysis of relevant historical sources shows how important a protective role these fossils played and were therefore not chosen at random for the crown. Thanks to medieval literary sources, it can be assumed that the motivation for the use of toadstones was protection against poison, but their possible other curative functions are not ruled out, and further research will be directed in this direction. These sources can be further connected on the basis of depictions of so-called toadstones in early modern prints, which allow them to be identified with fossil teeth and thus demonstrate a long and interesting tradition of using toadstones for medicinal and protective purposes, which is also reflected in the Imperial royal crown.

SOUHRN

Cášská koruna zdobící relikviářovou bustu Karla Velikého v pokladnici katedrály Panny Marie v Cáchách je dodnes opředena nejasnostmi o své provenienci i době vzniku. Dva knoflíkovité zuby fosilní ryby druhu *Scheenstia maximus* (Wagner, 1863) jsou naprostou výjimečností na tak významné středověké insignii a jejich zasazení na koruně se vymyká tradičnímu využití drahých kamenů na uměleckých předmětech středověku. Předběžná analýza historických pramenů ukazuje, že tyto fosilie hrály významnou ochrannou roli a nebyly pro korunu vybrány náhodně. Díky středověkým literárním pramenům lze předpokládat, že motivací užití ropuších kamenů byla ochrana před jedem, ale nevylučuje se i jejich případná další kurativní funkce a tímto směrem bude orientován i další výzkum. Tyto prameny lze dále propojit na základě zobrazení tzv. ropuších kamenů v raně novověkých tiscích, které je dovolují identifikovat s fosilními zuby a dokládají tak dlouhou a zajímavou tradici užívání ropuších kamenů pro léčivé a ochranné účely, která se zrcadlí také v cášské královské koruně.

ACKNOWLEDGEMENTS

This paper appears through the institutional support of long-term conceptual development of research institutions provided by the Ministry of Culture (ref. MK000094862). We thank Andrea Tintori (Università degli Studi di Milano) for literature and discussion concerning Italian records of fossil durophagous fishes, Martin Ebert (Jura-Museum Eichstätt) for comments about *Scheenstia* teeth from German localities, Mathias Harzhauser and Ursula Göhlich for providing comparative material for this study from the collection of Naturhistorisches museum Wien, Ortwin Schultz (Naturhistorisches museum Wien) for discussion about different types of dentition, and Birgitte Falk for enabling the study of the crown in the Aachener Domschatzkammer. We also thank the reviewers Lionel Cavin (Muséum d'histoire naturelle, Genève) and Šárka Hladilová (Masaryk University) for their helpful and important comments which improved the manuscript, Pavla Seitlová for translations from German.

PRIMARY SOURCES

Aldrovandi, U., 1648: Ulyssis Aldrovandi Musaeum metallicum in libros IIII distributum Bartholomaeus Ambrosinus... composuit, Bononiae (Typis Io. Battista Ferronii), 810–815.

Barrére, P., 1746: Observations sur l'origine et la formation des pierres figurées, et sur celles..., Paris (D'Houry pere et fils), 20.

Boodt, A. De, 1609: Anselmi Boetii de Boodt... Gemmarum et Lapidum Historia, qua non solum ortus, natura, vis et pretium, sed etiam modus, quo ex iis olea, salia, tincturae, essentiae, arcana et magisteria arte chymica confici possint, ostenditur..., Hanoviae (Claude de Marne et Johann Aubry), 152–153.

Gessner, K., 1565: Conradi Gesneri De Rerum Fossilium, Lapidum et Gemmarum maxime figuris et similitudinibus Liber..., Tiguri (Jakob Gessner), 161–163.

[H]ortus sanitatis, 1491: Ortus sanitatis, in civitate Moguntina (Jacobus Meydenbach), De Lapidibus, cap. 27, without pagination.

Imperato, F., 1599: Dell'historia naturale di Ferrante Imperato napolitano Libri XXVIII, nella quale ordinatamente si tratta della diversa condition di miniere, e pietre, con alcune historie di Piante & Animali..., Napoli (Costantino Vitale), 661.

Jussieu, A., 1723: De l'origine des pierres appelées Yeux de Serpents et Crapaudines. – Histoire de l'Académie royale des Sciences. Année M.DCCXXIII. Paris (Durand), Memoires, 205–210.

Klaret (Claretus de Solentia), Glossarius. In: Václav Flajšhans (ed.), Klaret a jeho družina, 1, Slovníky veršované, Praha (Česká akademie věd a umění), 1926, 109.

Merrett, Ch., 1667: Pinax Rerum Naturalium Britannicarum continens Vegetabilia, Animalia, et Fossilia..., Londini (T. Rycroft), 210.

C. Plinius Secundus, Historia Naturalis, lib. XXXVII. In: Eichholz, D. E. (ed., transl.), Pliny, Natural history. Books 36–37, Cambridge, Massachusetts (Harvard University Press), 1962, 284.

Scilla, A., 1670: La vana speculazione disingannata dal senso, Napoli (Andrea Colicchia), 67.

REFERENCES

Agassiz, L., 1832: Untersuchungen über die fossilen Fische der Lias-Formation. – Jahrbuch für Mineralogie, Geognosie, Geologie und Petrefaktenkunde (Stuttgart), 3, 139–149.

Agassiz, L., 1833–1844: Recherches sur les Poissons Fossiles, Neuchatel et Soleure (Petitpierre), 1420 pp.

Arratia, G., Schultze, H.-P., 1999: Semionotiform Fish from the Upper Jurassic of Tendaguru (Tanzania). – Mitteilungen aus dem Museum für Naturkunde in Berlin, Geowissenschaftliche Reihe, 2, 2, 135–153.

Arratia, G., Schultze, H.-P. Tischlinger, H., Viohl, G., 2015: Solnhofen – Ein Fenster in die Jurazeit. München (Verlag Dr. Friedrich Pfeil), 620 pp.

Bauer, R., Haupt, H. (Ed.), 1976: Das Kunstkammerinventar Kaiser Rudolfs II., Prag 1607–1611. – Jahrbuch der kunsthistorischen Sammlungen in Wien, 72, 1–191.

Bassani, F., 1885: Avanzi di pesci oolitici nel Veronese. – Atti della Società Italiana di Scienze Naturali (Milano, Bernardoni), 28, 142–163.

Bernard, A., 1977: Pan du desért. Leiden (E.J. Brill), 127.

Blaschke, F., 1911: Zur Tithonfauna von Stramberg in Mähren. – Annalen des Kaiserlich-königlichen Naturhistorischen Hofmuseums (Wien), 25, 143–221.

Bobková, L., 2003: Velké dějiny zemí Koruny české IVa. 1310–1402. – Paseka, 243–245.

Bodenstein, G., 1919: Urkunden und Regesten aus dem k. und k. Reichsfinanz-Archiv in Wien. – Jahrbuch der Kunsthistorischen Sammlungen des Allerhöchsten Kaiserhauses, 33, 16.

Brignon, A., 2015: Senior synonyms of *Ptychodus latissimus* AGASSIZ, 1835 and *Ptychodus mammillaris* AGASSIZ, 1835 (Elasmobranchii) based on teeth from the Bohemian Cretaceous Basin (the Czech Republic). – Acta Musei Nationalis Pragae, Series B Historia Naturalis, 71, 1–2, 5–14.

Brignon, A., 2019: Le Diodon devenu requin: l'histoire des premieres découvertes du genre *Ptychodus* (Chondrichthyes). Bourg-la-Reine (Édité par l'auteur), 13.

Buffetaut, E., Bülow, M., Gheerbrant, E., Jaeger, J.-J., Martin, M., Mazin, J.-M., Milsent, C., Rioult, M., 1985: Zonation biostratigraphique et nouveaux restes de vertébrés dans les «Sables de Glos» (Oxfordien supérieur, Normandie). – Comptes rendus de l'Académie des Sciences Paris, 2, 300, 929–932.

Cherry, J., 1992: Medieval craftsmen Goldsmiths. – University of Toronto Press, 22.

Cuny, G., Buffetaut, E., Cappetta, H., Martin, M., Mazin, J.-M., Rose, J.-M., 1991: Nouveaux restes de vertébrés du Jurassique terminal du Boulonnais (Nord de la France). – Neues Jahrbuch für Geologie und Paläontologie Abhandlungen, 180, 323–347.

DALTON, O. M., 1912: Franks bequest: Catalogue of the Finger Rings, Early Christian, Byzantine, Teutonic, Mediaeval and Later, bequeathed by Sir Augustus Wollaston Franks, K.C.B., in which are included the other rings of the same period in the Museum. London (British Museum), 142.

D'ERASMO, G., 1922: Catalogo dei pesci fossili delle Tre Venezie. – Memorie dell'Istituto Geologico della R. Università di Padova, 6, 181.

D'ERASMO, G., 1927: Su alcuni ittioliti del Museo Civico di Storia Naurale di Trento. – Studi trentini di scienze naturali, 2, 8, 198–208.

DUFFIN, C., 2008: Fossil as Drugs: pharmaceutical palaeontology. – Travaux scientifique du Musée national d'histoire naturelle Luxemburg, 34–44.

DUFFIN, C., 2010: The Toad Stone – a rather unlikely gem. – Jewellery History Today, Issue 8, 1–3.

ETHERIDGE, R., WILLETT, H., 1889: On the Dentition of *Lepidotus maximus*, Wagner, as illustrated by Specimens from the Kimeridge Clay of Shotover Hill, near Oxford. – Quarterly Journal of the Geological Society, 45, 356–358.

FORBES, T. R., 1972: Lapis Bufonis: The Growth and Decline of a Medical Superstition. – Yale Journal of Biology and Medicine, 45, 139–149.

GREGOROVÁ, R., DUFFIN, CH. 2019: The pre-scientific history of *Lepidotes* AGASSIZ, 1832. –Abstracts of the 90th Annual Meeting of the Paläontologische Gesellschaft, Munich 2019 (Paleontological Society), Munich, Paleo & Life, 52.

GRIMME, E. G., 1972: Der Aachener Domschatz. – Aachener Kunstblätter, 42, 88–90.

GUNDESTRUP, B., 1991: The royal Danish Kunstkammmer 1737. Vol. I–II., 158.

HARRELL, J. A., 2012: Ornamental Stones. In: Wendrich, W. (ed.), UCLA Encyclopedia of Egyptology. – University of California at Los Angeles. [online at http://digital2.library.ucla.edu/viewItem.do?ark=21198/zz002dwzs4], 7.

HARRELL, J. A., STOREMYR, P., 2009: Ancient Egyptian quarries – an illustrated overview. In: Abu-Jaber, N., Bloxam, E. G., Degryse, P., Heldal, T. (eds.), Quarry Scapes: ancient stone quarry landscapes in the Eastern Mediterranean. – Geological Survey of Norway, Special Publication, 12, 7–50.

HUYSKENS, A., 1938: Die Aachener Krone der Goldenen Bulle, das Symbol des alten deutschen Reiches. In: Deutsches Archiv für Geschichte des Mittelalters, 1–99.

KODIŠOVÁ, L., 2019: Materiály ke zlatnictví na dvoře Karla IV. : Zlatnické práce v zahraničí. Disertační práce, Univerzita Karlova, Katolická teologická fakulta, Ústav dějin křesťanského umění, 126.

KREJČÍ, J., 1859: Lapidarius český, o drahém kamení. Z rukopisu Vodňanského XIV. věku, nyní v muzeu, čten ve schůzce filologické královské České společnosti dne 19. června 1854. – Živa – časopis přírodnický (Praha), 7, 268–274.

LAZAR, I., PANAIOTU C. E., GRIGORE, G., SANDY, M. R., PECKMANN, J., 2011: An unusual brachiopod assemblage in a Late Jurassic (Kimmeridgian) stromatactis mud-mound of the Eastern Carpathians (Hăghimaş Mountains), Romania. – Facies. Carbonate Sedimentology and Paleoecology, 57, 627–647.

LEUZINGER, L., CAVIN, L., LÓPEZ-ARBARELLO, A., BILLON-Bruyat, J. P., 2020: Peculiar tooth renewal in a Jurassic ray-finned fish (Lepisosteiformes, †*Scheenstia* sp.). – Palaeontology, 63, 1, 117–129.

LINDAHL, F., 2003: Symboler i guld og sølv: Nationalmuseets fingerringe 1000-1700-årene. Det Kongelige Nordiske oldskriftselskab 23, Copenhagen, 235 pp.

LÓPEZ-ARBARELLO, A., 2012: Phylogenetic Interrelationships of Ginglymodian Fishes (Actinopterygii: Neopterygii). – PLoS ONE, 7, 7, e39370., 1–44.

LÓPEZ-ARBARELLO, A., SFERCO, E., 2011: New semionotiform (Actinopterygii: Neopterygii) from the Late Jurassic of southern Germany. – Journal of Systematic Palaeontology, 9, 2, 197–215.

OAKLEY, K. P., 1975: Decorative and Symbolic Uses of Vertebrate Fossils. – Occasional Papers on Technology, 12 (Oxford University Press), 20.

PARKINSON, J., 1830: Outlines of Oryctology. An introduction to the study of fossil organic remains; especially those found in the British strata – London, 259.

PEACOCK, D., MAXFIELD, V. (eds.), 2007: The Roman Imperial Quarries. Survey and Excavation at Mons Porphyrites 1994–1998. Vol. 2 – The Excavations. London (Egypt Exploration Society), 7.

PEYER, B., 1954: Ein Gebissfund von Lepidotus aus dem oberen weissen Jura von Thayngen, Kt. Schaffhausen Schweiz. – Schweizerische Paläontologische Abhandlungen, Basel (Birkhäuser), 70, 1, 1–20.

PEYER, K., CHARBONNIER, S., ALLAIN, R., LÄNG, É., VACANT, R., 2014: A new look at the Late Jurassic Canjuers conservation Lagerstätte (Tithonian, Var, France). – Comptes Rendus Palevol, 13, 5, 403–420.

PICTET, F. J., JACCARD, A., 1860: Description de quelques débris de reptiles et poissons fossiles: trouvés dans l'étage Jurassique supérieur (Virgulien) du Jura Neuchatelois. Genéve (J. Kessmann, H. Georg), 36.

PLETICHA, H., 1989: Des Reiches Glanz. Die Reichskleinodien und Kaiserkrönungen im Spiegel der deutschen Geschichte. – Freiburg i. B. (Flechsig Verlag), 240 pp.

Poche, E., 1965: Einige Erwägungen über die Kameen Karls IV. In: Sborník k semdesátinám Jana Květa. – Acta Universitatis Carolinae, Philosophica et Historica (Praha), 82–93.

Poche, E., 1982: Francouzské vlivy v českém uměleckém řemesle doby Karla IV. – In: Mezinárodní vědecká konference: Doba Karla IV. v dějinách národů ČSSR, Univerzita Karlova, 283–285.

Remeš, M., 1897: Ryby tithonu štramberského. – Rozpravy České akademie císaře Františka Josefa pro vědy, slovesnost a umění v Praze, třída II, 6, 1–8.

Sasagawa, I., Ishiyama, M., Yokosuka, H., Mikami, M., Uchida, T., 2009: Tooth enamel and enameloid in actinopterygian fish. – Frontiers of Materials Science in China, 3, 2, 174–182.

Schneider, S., Harzhauser, M., Kroh, A., Lukeneder, A., Zuschin, M., 2013: Ernstbrunn Limestone and Klentnice beds (Kimmeridgian–Berriasian; Waschberg-Ždánice Unit; NE Austria and SE Czech Republic): state of the art and bibliography. – Bulletin of Geosciences, Prague (Czech Geological Survey), 88, 1, 105–130.

Sirna, G., Vecchia, F.M.D., Muscio, G., Piccoli, G., 1994: Catalogue of Paleozoic and Mesozoic Vertebrates and Verrtebrate localities of the Tre Venezie area (North Eastern Italy). – Memorie di Scienze Geologiche 46, 55–281.

Stütz, A., 1807: Mineralogisches Taschenbuch: enthaltend eine Oryctographie von Unterösterreich; zum Gebrauche reisender Mineralogen. Wien (Verlag Geistinger), 290.

Tuček, K., 1983: O kamenech prvního českého Lapidáře. – Časopis Národního muzea, oddíl přírodovědný (Praha), 152, 1, 37–60.

Wagner, A., 1863: Monographie der fossilen Fische aus den lithographischen Schiefern Bayern's. Abhandlungen der Königlich Bayerische Akademie der Wissenschaften, Mathematisch-Physikalischen Klasse, 9, 3, 611–748.

Zimerman, H., 1889: Inventare, Acten und Regesten aus der Schatzkammer des Allerhöchsten Kaiserhauses. – Jahrbuch der Kunsthistorischen Sammlungen des Allerhöchsten Kaiserhauses (Wien, Adolf Holzhauser), 10, CCLXV, 551.

Zittel, K. A., 1870: Die Fauna der aeltern Cephalopodenfuehrenden Tithonbildungen. – Palaeontographica. Beitraege zur Naturgeschichte der Vorwelt. Supplement. Cassel (Theodor Fischer), 22–24.

Žemlička, J., 2005: Rituál přísahy a korunovace Václava II. K obrazu dvora posledních Přemyslovců. In: Lesk královského majestátu ve středověku. Pocta Prof. Phdr. Františku Kavkovi, CSc. k nedožitým 85. narozeninám, uspořádaly Lenka Bobková a Mlada Holá, Praha – Litomyšl 2005, 36–37.