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Artículo

Stone monuments and abandoned quarries –ways of restoration in Germany through times

Monumentos de piedra y canteras abandonadas – formas de restauración en Alemania a través del tiempo

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Abstract: Numerous buildings and monuments in the cultural heritage in Germany are made of stone. Increasingly, quarries are closing and the original stone is no longer available as a substitute material. Various ways of dealing with this situation in the past are presented here using 6 examples: Cologne Cathedral, Freiburg Münster, the Stone Bridge in Regensburg, Kaiser-Wilhelm-Monument at Porta Westphalica, Old National Gallery in Berlin and the Picture Gallery of Sanssouci Palace in Potsdam. It is shown how the replacement stones were selected at different times and under different economic and political conditions when the original rock was no longer available. In two cases, old quarries were (temporarily) reactivated. For the other buildings, other, available stones were used for restoration or reconstruction. In one example, this replacement was reversed after the original material became available again. The ways of decision-making, advantages and disadvantages as well as experiences are presented and discussed in this contribution.

Keywords: Building stones; decoration stone; quarry; stone restoration

Key points:

Natural stone, which shapes the character of many historical buildings and monuments of the cultural heritage, needs to be maintained and sometimes replaced just like any other building material.

The examples from Germany show that the material-appropriate use of building stones in the preservation of our cultural monuments can only be realised if both the decision-makers and the natural stone companies involved have the will and the knowledge to do so.

It is very important provide data on natural stone and inform people about their importance for the appearance of the historic buildings and cultural landscapes.

Resumen: Numerosos edificios del patrimonio cultural alemán están hechos de piedra. Cada vez más se cierran canteras, impidiendo la disponiblidad de la piedra original como material sustitutivo. ¿Cómo afrontar esta situación?. A partir de 6 ejemplos se presentan diferentes posibilidades: la Catedral de Colonia, Friburgo *Münster,* el Puente de Piedra de Ratisbona, el Monumento al Emperador Guillermo de Porta Westfalica, la Antigua Galería Nacional de Berlín y la Pinacoteca del Palacio Sanssouci de Potsdam. Se muestra cómo se seleccionaron las piedras para el reemplazo en diferentes momentos y bajo diferentes condiciones económicas y políticas, cuando la roca original ya no estaba disponible. En dos casos, se reactivaron (temporalmente) antiguas canteras. Para los demás edificios se utilizaron otras piedras disponibles para la restauración o reconstrucción. En un ejemplo, este reemplazo se revirtió posteriormente, una vez que el material original volvió a estar disponible. En esta contribución se presentan y discuten las formas de toma de decisiones, con sus ventajas y desventajas, así como las diversas experiencias.

Palabras clave: Piedra de construcción; piedra decorativa; cantera; restauración de piedra

Puntos clave:

La piedra natural, que define el carácter de numerosos edificios históricos y monumentos del patrimonio cultural, requiere mantenimiento e, incluso, reemplazo, como cualquier otro material de construcción.

Los casos de Alemania demuestran que el uso adecuado de la piedra natural en la conservación de nuestros monumentos culturales solo es posible si tanto los responsables de la toma de decisiones como las empresas especializadas cuentan con el conocimiento necesario y el compromiso para hacerlo realidad.

Es fundamental recopilar y compartir información sobre la piedra natural, así como sensibilizar a la población sobre su importancia para la preservación de los edificios históricos y los paisajes culturales.

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Supplementary information ↓

1. INTRODUCTION

A look at the map of Germany's surface geology shows a clear three-way division from north to south (Fig. 1): the entire north is characterised by the deposits of the last ice ages. The central part is dominated by sedimentary rocks from the Upper Carboniferous to the Cretaceous, supplemented by some bedrock outcrops in the low mountain ranges with igneous and rarely also metamorphic rocks. The south is characterised by the northern edge of the Alps and the Alpine foothills, which are also covered by glacial deposits (Meschede & Warr, 2019).

Over the centuries, especially since around 1000 years ago, the softer rocks (sandstones, limestones, tuffs) were initially preferred for construction throughout the central part of the country, and since the 19th century the hard rocks have also been quarried and used for construction purposes.

It is estimated that there have been around 50,000 to 80,000 extraction sites and quarries in Germany over the centuries (Ehling *et al*., 2019). For centuries, the building stones were also transported by river to areas where natural stone was not available. The prestigious buildings in Berlin, for example, were built using sandstone that was transported over 400 kilometres from the Elbsandsteingebirge via the rivers Elbe, Havel and Spree (Ehling & Siedel, 2011). Today there are still around 250 quarries that extract natural stone (Grimm, 2018). Many of the natural stones that characterise the face of our historical buildings, our cultural heritage, are no longer available for preservation. This also includes rocks that are unique in their appearance and properties.

How was is dealt with this problem in Germany in the context of preserving and restoring of the stone cultural heritage? What is the legal basis?

Germany is a federal country and additionally was divided for 40 years. This means that in each federal state there are different legal bases with regard to quarrying licences for natural stone and also with regard to monument conservation principles; even if in the latter case the Venice Charter basically forms the basis for monument conservation decisions. In some federal states, quarries are subject to

mining law, in others not. In some, there is a mining law that allows the extraction of up to 30 cubic metres of stone without a mining permit.

Some alternatives to solve the problem of no longer available building stones are given on the basis of several representative examples.

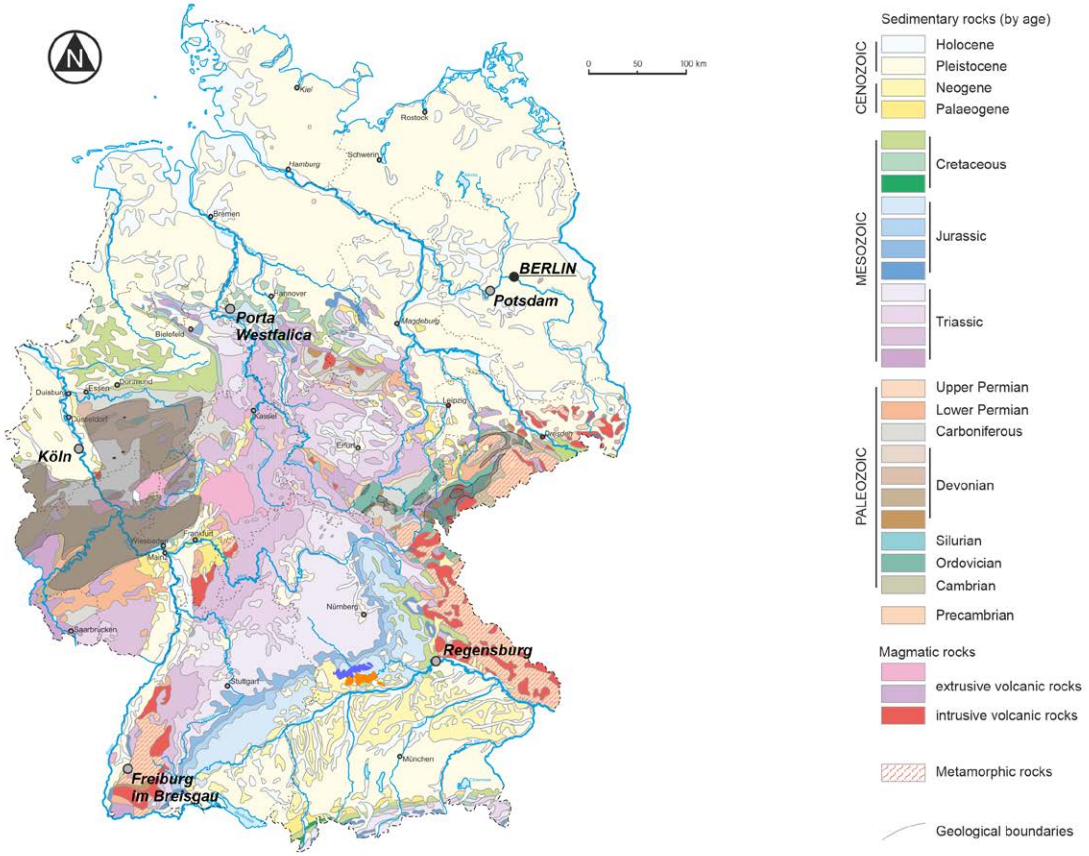

Figure 1. Geological map of Germany (BGR) with mentioned localities.

Figura 1. Mapa geológico de Alemania (BGR) con las localidades mencionadas.

2. COLOGNE CATHEDRAL

The 19th century, with the emergence of a national consciousness in the German states, was the origin of state-funded monument preservation in Germany. Initially, it was mainly churches that were restored or, in some cases, completed (Kiesow, 2000).

One of the best-known examples is Cologne Cathedral, one of Germany's stone landmarks and since 1996 recognized as UNESCO world Heritage site (https://whc.unesco.org/en/list/292). It was built over centuries from 1248 to 1880 with a long interruption of 300 years between the 16th and the 19th century. In 1842 the completion of the cathedral started as a national task. The dominant building stone of the old parts was Drachenfels trachyte (44 kilometres away), which was quarried already by the Romans and transported to Cologne and other cities via the Rhine. This was probably the first time that the problem of an unavailable building rock for a prominent building arose, as the Drachenfels and therefore also the quarries had been a nature reserve since 1836 - one of the first nature reserves in Germany. There is hardly any similar stone like this trachyte in Germany (Fig. 2).

For this reason, both the construction phase, from 1842 to 1880, and the later restoration phases were characterised by the constant search for replacement stones. During the completion phase, other volcanic rocks in the surrounding area were first used and finally 11 different sandstones from several parts of Germany were used. This period is called the "sandstone age of the Cologne Cathedral" (Fig. 3).

Figure 2. Original Drachenfels trachyte in the upper part and Londorf basaltlava as a replacement in the lower part at the Cologne Cathedral (photo Angela Ehling).

Figura 2. Traquita original de Drachenfels en la parte superior y basaltolava de Londorf como reemplazo en la parte inferior de la Catedral de Colonia (foto de Angela Ehling).

Figure 3. White Obernkirchen sandstone as a replacement stone at the Cologne Cathedral (photo Angela Ehling).
Figura 3. Arenisca blanca de Obernkirchen como piedra de reemplazo en la Catedral de Colonia (foto de Angela Ehling).

The repair and restoration in the first half of the 20th century is marked as the "limestone age" due to the preferred use of limestones throughout Germany at that time. Large parts have been reworked with Krensheim Muschelkalk, supplemented by Eifel basalt in hidden areas accordingly to doubts about the durability of the limestone.

After 1945 various stones have been used for repair and restoration. Until the turn of the 21st century the Londorf basalt nearby was the preferred replacement stone. Since 2005 the Monte Merlo trachyte from Italy has been used as a replacement for the Drachenfels trachyte and the sandstones from Radkow/Poland and Boshanov/Czech Republic are replacing the meanwhile weathered sandstones from the 19th century (von Plehwe-Leisen & Leisen, 2022).

Together with the particular suitable sculpture stones there are more than 50 different stones today at the Cologne Cathedral. The choice of replacement stones at different times depended on various factors: availability in sufficient quantities, transportation options, fashion trends, some times even personal preferences and relationships, and only in the last 20 years a trachyte from Italy, a rock similar to the original Drachenfels trachyte, has been used again.

3. KAISER WILHELM MONUMENT AT THE PORTA WESTFALICA

The Kaiser Wilhelm Monument (1896) is one of the last major national monuments to place the emperor at the centre of the culture of remembrance at the end of the 19th century (Fig. 4). With a height of 88 metres and situated 268 metres on a mountain above the river Weser, it is a very striking landmark visible from afar.

The statue of the emperor is made of pewter. It stands on a stone pedestal. The foundation is formed by a circular terrace 120 metres in diameter, supported by a circular wall. All these components were made of Porta sandstone, which was quarried not far from the monument in reactivated old quarries as well as in an underground mine nearby. This Porta sandstone is a Jurassic yellow-brown, coarse-grained to conglomeratic Fe-rich sandstone with distinctive Fe mineral enrichments and structures. It has been quarried and transported along the river Weser as far as to the North Sea since 1000 years and more than 100 churches had been built with this sandstone (Ebel & Ehling, 2012). There is no similar sandstone in Germany and since the closure of the last quarry 1952, the sandstone is no longer available for building and restoration purposes.

As part of a diploma thesis (Pahl, 2011), the historical quarries were evaluated, their current status documented and locations for possible limited extraction postulated. Of the 13 historic quarries analysed, 11 are located in a nature and landscape conservation area (fauna-flora habitat area) and are also subject to geotope protection. 2 former quarries are on private land. This means that for limited extraction, either the protected status would have to be partially cancelled or the private owner would have to agree.

As a result of subsidence and, above all, the blasting of the former mining tunnel underneath in 1948 (used for the production of armaments during the Second World War), parts of the circular terrace and the fundamental wall no longer existed or were severely damaged. In 2013, it was decided to reconstruct the circular terrace and also to build a visitor centre with a restaurant. In addition to large quantities of reinforced concrete and concrete to secure the subsoil, large quantities (more than 700 cubic metres or 2000 tonnes) of sandstone were required. A quantity that could not be obtained in Porta sandstone.

The search for a suitable sandstone for the reconstruction was short. After price negotiations for an optically somewhat similar sandstone in Ibbenbüren were unsuccessful, the decision was made in favour of the nearest sandstone from Obernkirchen. This is a building sandstone of high quality, also used since several centuries, even throughout Europe. But this Obernkirchen sandstone is white, fine-grained, i.e., it bears no resemblance to the original Porta sandstone, neither visually nor in terms of its other properties.

The decision in favour of this sandstone, which was not really suitable, was accompanied by the comment in the press that after decades it would take on a dark surface anyway and the difference would no longer be perceptible from a distance (Fig. 4) (Beyer, 2018).

Figure 4. Monument Kaiser Wilhelm at Porta Westfalica with original brown Porta sandstone at the monument and new white Obernkirchen sandstone at the wall (photo Peter Hübbe).

Figura 4. Monumento a Kaiser Wilhelm en Porta Westfalica con la arenisca marrón original de Porta en el monumento y nueva arenisca blanca de Obernkirchen en el muro (foto de Peter Hübbe).

4. ALTE NATIONALGALERIE AT THE MUSEUM ISLAND IN BERLIN

This museum was the third built museum at the Museum Island in Berlin; UNESCO World Heritage since 1999 (https://whc.unesco.org/en/list/896). It was built between 1866 and 1876, with architecture reminiscent of a Greek temple. All facade and architectural elements were made of a Buntsandstein from Nebra, a little village in Sachsen-Anhalt at the river Unstrut (Fig. 5). The last quarries there closed in the 1960s. Suitable replacement stones were sought as part of the extensive restoration around 1990. The Nebra sandstone offered a wide variety of colours: white, grey, light yellow, pink, salmon-couloured and red. The facade is dominated by pink and salmon-coloured varieties. Sandstones with these coulours could not been provided by other quarries. For this reason, two companies reopened quarries near Nebra and supplied the required replacement stones. It was a direct co-operation between the Office for the Preservation of Historical Monuments and the quarry companies (Ehling & Siedel, 2011). One of the quarries is still open for restoration purposes (Fig. 6).

Figure 5. Alte Nationalgalerie at the Museums Island in Berlin (photo Ulf Schönitz).
Figura 5. Alte Nationalgalerie en la Isla de los Museos en Berlín (foto de Ulf Schönitz).

Figure 6. Sandstone quarry near Nebra; extraction almost only for restoration purpose (photo Angela Ehling).
Figura 6. Cantera de arenisca cerca de Nebra; extracción casi exclusivamente con fines de restauración (foto de Angela Ehling).

5. STONE BRIDGE IN REGENSBURG

Built entirely of stone between 1135 and 1146, the bridge is considered a masterpiece of medieval architecture and is the oldest surviving bridge in Germany (Fig. 7). It is part of the Old town of Regensburg, a UNESCO World Heritage site.

The bridge was entirely built of Regensburg Grünsandstein, a green sandstone from the region around the city (Poschlod, 2022). Non of the quarries was active when the bridge should be restorated in 2018.

In the run-up of the planned restoration the Bavarian Geological Survey (LfU) was commissioned to explore and investigate the deposits of Regensburg Grünsandstein with regard to their suitability as a replacement stone and their extraction potential. The sandstone is very inhomogeneous in its mineral content (glauconite content and proportion of mussel shell remains), which makes it difficult to find suitable material. 13 exploratory boreholes were drilled + 4 further boreholes near a former quarry, many samples were taken and analysed. At a result, 5 potential areas could be held out; 2 of them could provide qualitatively recommendable building sandstone (Poschlod *et al*., 2017a). All in all, a thorough and exemplary approach.

Finally, for reasons that are not clear, the restorers decided to use a granite for replacement (Fig. 7).

Figure 7. Stone bridge in Regensburg after restoration with new granite railing (photo Klaus Poschlod, 2018).

Figura 7. Puente de piedra en Ratisbona después de la restauración con una nueva barandilla de granito (foto de Klaus Poschlod, 2018).

6. MÜNSTER IN FREIBURG

Freiburg Münster (1200-1513), although started in the Romanesque style, is considered a masterpiece of Gothic architecture, especially, its beautiful west tower. The impression of a work of art from a single mould is largely determined by the building stones, which over the 300 years of construction, mainly consists of red and yellow Bunter sandstone (Fig. 8). After several years of research in archives

and investigations of the sandstones from historical quarries in the surrounding area, various quarries were identified as suppliers of building stone in different construction phases. In the 20th century, sandstone from more distant regions was used for repair work, as the historic quarries were no longer in production or could no longer supply suitable material.

Figure 8. Freiburg Münster (photo Angela Ehling).

Figura 8. Münster de Friburgo (foto de Angela Ehling).

As part of the extensive restoration work in our century, research into the historical quarries for Freiburg Münster was intensified and one of these quarries was reactivated in 2014. Since then, the sandstone from this quarry has been used again as a replacement material (Fig. 9) (Brehm *et al.*, 2022).

Figure 9. New pieces for the Freiburg Münster made of the sandstone from the reactivated quarry Tennenbach, to the right an old element of the Freiburg Münster made of the same sandstone, Dombauhütte (photo Angela Ehling).

Figura 9. Nuevas piezas para el Münster de Friburgo hechas con arenisca de la cantera reactivada de Tennenbach; a la derecha, un elemento antiguo del Münster de Friburgo hecho con la misma arenisca, Dombauhütte (foto de Angela Ehling).

7. PICTURE GALLERY IN POTSDAM SANSSOUCI – UNESCO WORLD HERITAGE SITE

This example is not regarded to abandoned quarries but to the non-availability of the original stone due to political and economic barriers. It also shows that the right choice of a stone can make a big difference.

The Picture Gallery in Sanssouci Park (Fig. 10), which King Frederick II (the Great) of Prussia had built between 1755 and 1764, not only houses an excellent collection of paintings, but is also a particularly fine example of the diverse use of coloured natural stones in Potsdam's 18th century palaces.

Figure 10. Picture Gallery Potsdam, Park Sanssouci, © SPSG, Michael Lüder, 2005.
Figura 10. Galería de arte de Potsdam, Parque Sanssouci, © SPSG, Michael Lüder, 2005.

With the exception of the ceiling and the wooden wall for the paintings, the gallery room, which is over 80 metres long, is a completely marble-panelled hall. In addition to the incrusted wall panels made of marble *Giallo antico*, the floor made of yellow and white marble diamonds plays a particularly important role in the staging of the light in this extremely festive-looking room.

The floor was covered in a chequerboard pattern with white Carrara slabs and slabs from *Giallo* and *Brocatello di Siena*. An unfavourable room climate, which was sensitive to seasonal fluctuations in humidity and temperature and even frost, caused considerable damage to the Sienese marble slabs.

In 1961, the original slabs of *Giallo* and *Brocatello di Siena* were removed from the floor and replaced with a reddish-brown nodular limestone from Saalburg / Thuringia (Fig. 11). As the political and economic conditions in the German Democratic Republic (GDR) made it impossible to purchase natural stone in Italy, natural stone was sourced domestically. The fact that the gallery lost its harmonious and radiant colour scheme of white, yellow and gold due to the dark, light-absorbing Saalburg 'marble' slabs had to be accepted.

After just 30 years, it became apparent that the continuing extreme climatic fconditions had led to the partial surface dissolution of the Saalburg 'marble'. The decision to install a heating system in the gallery floor provided the opportunity to consider reconstructing the yellow marble slabs. The unification of Germany in 1990 made it possible to turn back to Italy.

Initially, scepticism was heard from there regarding the availability of the material in the required quality and quantity. With the support of two companies from Colle Val d'Elsa and Rosia, the targeted extraction of the marble and the cutting of the required 1,400 marble slabs of *Giallo* and *Brocatello di Siena* could be realised. By returning the floor to the originally intended colour combination -consisting of the old, preserved Carrara slabs and the material-identical reconstructed slabs from the two varieties of Siena marble - the picture gallery was able to regain its splendid 18th century spatial impression. The work was completed in 1996 (Fig. 10).

Figure 11. Picture Gallery 1995 with the red nodular limestone slabs and some newly aquired Italian marble slabs Giallo di Siena (photo Stefan Klappenbach SPSG, 1996).

Figura 11. Galería de arte en 1995 con las losas de piedra caliza roja nodular y algunas nuevas losas de mármol italiano Giallo di Siena (foto de Stefan Klappenbach SPSG, 1996).

8. SUMMARY AND OUTLOOK

Only the reuse of original, indigenous natural stone respects and strengthens the cultural landscape“ (Poschlod *et al*., 2017b).

Three of the examples show that it is sometimes possible to reopen quarries or to temporarily extract a certain amount of stone or even to redempt a wrong stone replacement, when it refers to the restoration of very important architectural monuments given there is the will for this on part of both the authorities and the quarry industry.

Inspired by the exploration of the Regensburg green sandstone, the project to record historical natural stone deposits as a basis for their environmentally friendly reactivation for the purpose of restoring nationally significant cultural assets in Bavaria was funded by the German Federal Environmental Foundation (DBU).

51 quarries with 45 different types of rock were visited, documented and analysed in terms of petrography, mineralogy, geochemistry and rock technology. The results of the investigations are summarised in the final report and the samples, including sample slabs of all the rocks examined, are archived in an exemplary manner (Poschlod *et al*., 2017b).

This project is forward-looking. In addition to the image atlas of important monumental stones in Germany (Grimm, 2018) there should be a collection of historical building stones, as well as information on historical quarries and possible reactivation of quarries or extraction of stones.

However, the examples also show that the material-appropriate use of building stones in the preservation of our cultural monuments could only be realised if both the decision-makers and the natural stone companies involved had the will to do so.

It is therefore still important to inform and educate people about the importance of natural stone for the appearance of our historic buildings and cultural landscapes. The work of the IUGS Subcommission of Heritage Stones and the designation of the IUGS Heritage Stones also contributes to this (Ehling *v*., 2024).

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Authorship contribution statement

Angela Ehling: Conceptualization, Formal analysis, investigation, project administration, validation, Writing – original draft, Writing – review & editing.

Rainer Ebel: Formal analysis, investigation, Writing – original draft.

Competing interests

The authors of this article declare that they have no financial, professional, or personal conflicts of interest that could have inappropriately influenced this work.

Statement on the use of Artificial Intelligence

Not applicable.

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