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Artículo

Ancient and modern quarries of building stones in North-East France: main limestone deposits and rock types

Canteras antiguas y modernas de piedra para la construcciónen el noreste de Francia: principales yacimientos y tipos de calizas

Gilles Fronteau
Université de Reims Champagne-Ardenne, GEGENA, F-51100 Reims, France
Corresponding author: gilles.fronteau@univ-reims.fr, https://orcid.org/0000-0001-5817-4570

Patricia Vazquez
Université de Reims Champagne-Ardenne, GEGENA, F-51100 Reims, France
https://orcid.org/0000-0002-5392-6451

Théo Krauffel
Université de Reims Champagne-Ardenne, GEGENA, F-51100 Reims, France
https://orcid.org/0009-0000-1657-9887

Abstract: The north-east of France is mainly occupied by the Paris Basin, which has provided a significant quantity of building stone, particularly limestones used as dimension stone. A series of famous quarries have left their mark on the local area, from the Jurassic (Dom, Euville, Savonnières) to the Cenozoic layers (Hermonville, Courville), while others have been forgotten. These building stones are sometimes used on their own or mixed with more local materials that are less valued or with other properties. Some of these quarry areas have stones which were exported, competing with stone from Belgium, Burgundy and the Paris region. By comparing old maps and archives with quarries and stones that are still accessible, it is possible to draw up a number of assessments of the geological signatures of each limestone (facies, microfacies, petrophysical features). This allows us to gain a deeper insight into the utilisation of these building stones and to attempt to refine the restoration of cultural heritage.

Keywords: Building stone; Limestone; Provenance; France; Map

Key points:

The Paris Basin has been the driving force of construction in North-East France since the Roman era, providing essential limestones from the Jurassic and Cenozoic periods.

Due to the loss of historical records, rocks are grouped by common characteristics to track their use from local projects to exports exceeding 100 km.

The massive closure of quarries since the 19th century complicates the repair of monuments today, forcing the import of materials from other regions or countries.

Resumen: El noreste de Francia está principalmente formado por la Cuenca de París, que ha proporcionado una cantidad significativa de rocas industriales, particularmente calizas usadas como piedra de construcción. Una serie de canteras famosas han dejado su huella en la zona local, con edades desde el Jurásico (Dom, Euville, Savonnières) hasta las capas del Cenozoico (Hermonville, Courville), mientras que otras han sido olvidadas. Estas piedras se usan en algunas ocasiones como *único* material en la construcción, y en otras mezcladas con materiales más locales que son menos valorados y con diferentes propiedades. Algunas de estas *áreas* de canteras tienen piedras que fueron exportadas, compitiendo con las piedras de Bélgica, Borgoña y la región de París. Al comparar mapas antiguos y archivos con canteras y piedras que todavía son accesibles, es posible

realizar una serie de evaluaciones de las firmas geológicas de cada caliza (facies, microfacies, características petrofísicas). Esto nos permite obtener una comprensión más profunda sobre la utilización de estas piedras de construcción e intentar mejorar la restauración del patrimonio cultural.

Palabras clave: Canteras; calizas; Francia; Roca industrial; Cartografías

Puntos clave:

La Cuenca de París ha sido el motor de la construcción en el noreste de Francia desde la época romana, proveyendo calizas esenciales del Jurásico y Cenozoico.

Ante la pérdida de registros históricos, se agrupan las rocas por características comunes para rastrear su uso desde obras locales hasta exportaciones a más de 100 km.

El cierre masivo de canteras desde el siglo XIX dificulta hoy la reparación de monumentos, obligando a importar materiales de otras regiones o países.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

In France, dimension stone has been widely used since the Roman conquest, with the utilization of large-cut stone for the construction of monuments. This remained a significant aspect of the country's economy until the 20th century, when it was superseded by concrete construction techniques, which led to the gradual disappearance of quarries.

The durability of quarries within the landscape varies considerably across the different regions of France and their respective sociological, geological and climatic contexts. In southern France, old quarries are relatively well preserved. However, this is not the case in the north of the country, where most of the sites have disappeared due to vegetation overgrowth and land recultivation. The problem is particularly pronounced in the Paris Basin, characterized by intensive agriculture and dense vegetation, where numerous clay or sand layers tend to mask the limestone layers, which are often relatively thin.

Our study area is situated in the north-eastern regions of France, where the existence of ancient quarries remains relatively unknown. The monuments and remnants of towns from Antiquity and the Middle Ages provide evidence of the existence of supply routes for dimension stones. However, the quarries that can be attested to as dating from these historical periods are scarce, and even non-existent in some geographical areas.

Over the past three decades, research has been conducted by several academic groups, including historians, archaeologists, and a select few geologists with expertise in the field of exploitation and use of building materials. The knowledge of the distribution of the ancient stone quarries remains

incomplete, particularly in comparison to the extensive built heritage of these regions. Nevertheless, methodologies, case studies and general summaries have been produced. These have demonstrated the nature of the main types of rock used and the broad outlines of the organization of stone supplies from quarries to building sites. While in most cases the ancient quarries are still unknown, the information available shows the great diversity of supply strategies, both over time, according to micro-regions and according to needs in terms of types of geomaterials.

2. CONTEXT OF THE STUDY AREA AND METHODOLOGY

2.1. The east of the Paris Basin

The north-east of France represents a particularly interesting study area, given that it is largely dominated by one main geological context: the Paris Basin. However, this sector also displays a heterogeneous distribution of layers capable of supplying dimensional stone, and numerous urban centers with a major built heritage. From a historical perspective, the region has been subjected to a complex series of territorial changes, with instances of independence or attachment to other entities, as well as periods of unified governance. In addition, the north-east of France is not solely constituted by, or influenced by, the Paris Basin, a vast Meso-Cenozoic sedimentary unit. It is also shaped by the southern edge of the Ardenne massif, limited to the east by the Vosges unit and the northern extremity of the Massif Central (the Morvan), which are geological units comprising Paleozoic bedrocks, and characterized by the presence of magmatic and metamorphic rocks.

The Paris Basin is distinguished by a series of sedimentary layers that exhibit minimal tectonic activity in comparison to the southern regions of France. In the eastern part of the basin, the layers are arranged in a series of concentric aureoles, with the center of the series corresponding to the location of Paris. The age of the aureoles increases from the center of the basin outwards, from the Neogene to the Triassic in the east (Figure 1). These concentric formations are circumscribed by marked cuestas, which are linked to the presence of more resistant layers and softer layers, for example alternating limestone and clay beds. This gives rise to distinct micro-regions for example, the Champagne area which is of particular interest in the context of our study. This micro-region is comprised of two distinct sub-units: the chalky Champagne, situated on layers of Upper Cretaceous chalk (Turonian to Campanian), and the humid Champagne, located on marly and clayey layers from the Albian to the Cenomanian. Going further towards Paris, the geological substratum is constituted by Cenozoic layers, predominantly Paleogene, with sands, marls, clays, limestones and siliceous rocks. Conversely, in the peripheral areas of the basin, the layers are of older ages, Jurassic to the north with marls and limestones, or Jurassic and Triassic to the east and south, with sandstones, marls and limestones.

In the study area, only a few sites do not belong to the sedimentary units of the Paris Basin. These are located to the north of Charleville-Mézières (Figure 1), on the border with Belgium, where Cambrian and Devonian shales, quartzites and massive limestones predominate, and to the south-east, with few Paleozoic magmatic outcrops.

Regarding the built cultural heritage, the study area is home to a significant number of major monuments, despite the extensive damage caused by armed conflicts. The First World War resulted in the extensive destruction of numerous historical buildings in Champagne (Reims) and Lorraine (Verdun). The Second World War had a particularly detrimental impact on the Ardennes region, located in the north of the study area. Nevertheless, the region boasts several Gallo-Roman monuments, cathedrals and medieval fortifications, as well as a significant religious, military and civil heritage dating from the Modern and Early Modern periods. The identification of the stones that make up this cultural heritage and the search for their original quarries are justified by the need to preserve it.

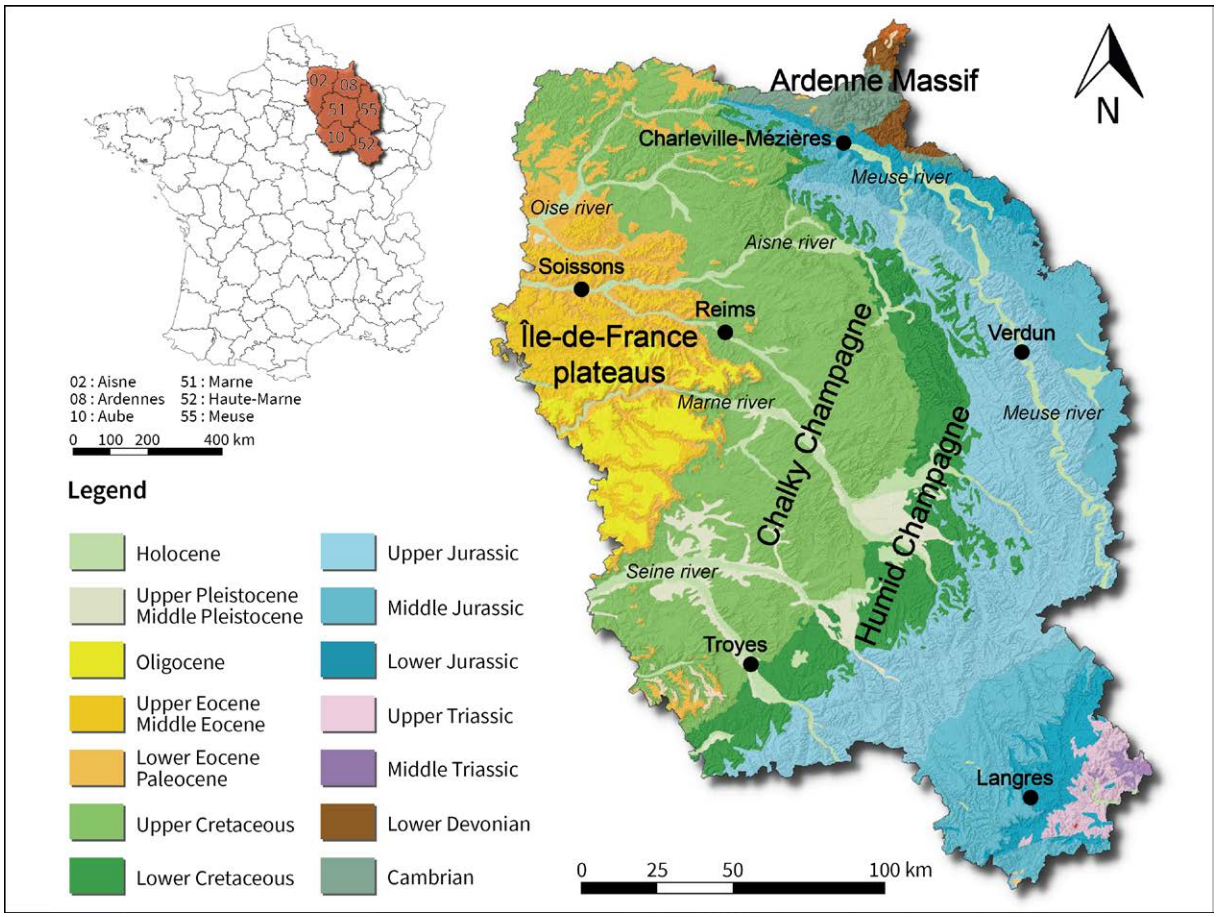


Figure 1. Geographical and geological settings of the studied zone.

Figura 1. Situación geográfica y geológica de la zona de estudio.

2.2. Methodology and main reference sources on old quarries

The methodologies employed in the study of ancient quarries or provenance of cultural heritage stones may vary considerably, depending on the specific case study, the issues under investigation, or the specialisms of the researchers involved (historians, archaeologists or geologists).

In addition to the archaeologists engaged in planned or rescue excavations, a few historians and archaeologists have conducted one-off studies on ancient quarries or on the stones produced in the study area, either as part of their doctoral thesis or as part of specific research programs. The findings of these individual or collective studies have been presented at several scientific symposia series, which serve as reference for the French scientific community interested in this subject (symposia “Carrières et Constructions” and symposia “Pierre à Pierre”). The dissemination of this knowledge internationally is limited, as the conferences and their publications are mostly in French (Fronteau *et al.*, 2019; Blary & Gély, 2020), but they constitute indispensable references for the study of ancient quarries, offering a wealth of results and case studies. Finally, a few summary books on these very old quarries, whether ancient or medieval, have been written. These books have been authored by specialists in stone cutting or quarrying, or by historians and geologists working together.

Building on this earlier works and drawing on our studies, conducted across a significant portion of north-east France, we propose here a targeted review of a few methodological points and key results on the ancient quarries in this study area.

3. MAIN ANCIENT QUARRIES IN NORTH-EASTERN REGION OF FRANCE

3.1. Protohistoric periods and Antiquity

In the north-eastern region of France, the list of recognized Gallo-Roman quarries is notably scarce. Only two sites are frequently referenced in academic literature due to their early discovery: the quarries of Norroy-lès-Pont-à-Mousson and Fontaine-sur-Marne. Other ancient extraction sites have been identified fortuitously through the archaeological diagnosis procedure that currently exists at the French national level or through research projects specifically dedicated to the subject. These recent discoveries have enabled the study of several previously unexamined ancient quarries. Nevertheless, most of the available information on these sites has not yet been widely disseminated or published. For example, several discoveries have been made of protohistoric or ancient quarries used to make grindstones, which attest to the existence of an extractive tradition and a good knowledge of stone deposits prior to the Roman conquest and the intensive use of stone for construction. It is also worth mentioning the recent archaeological discoveries and excavations (between 2017 and 2020) of Gallo-Roman quarries in the chalk of northern France.

Furthermore, the numerous studies conducted on the stones used in ancient buildings highlight significant gaps in our knowledge on the subject (Coquelet *et al.*, 2013). Given the diversity of stones used in construction, confirmed by macroscopic observation and petrographic analysis, it is clear that many antique local to regional quarries must exist, just as there must also be a network for the distribution from the quarries to the buildings. It is only regrettable that the locations from which these stones were extracted are not known.

For this historical period, we think that the vast area corresponding to chalky Champagne represents a highly promising sector for further study. Because this area lacked the rock necessary for large-scale structures, necessitating the importation of materials from distant locations. Several areas of influence seem to be in evidence (Figure 2). Cenozoic limestones of the Lutetian identical or close to those used in Reims (Bart, 2017; Fronteau *et al.*, 2022), coming from the north-west or west (Lutetian Soissonnais types) are observed in numerous antique sites near Reims or in the Suippe and Vesle valleys. Some Jurassic strata, in particular the oolitic limestones of the Novion-Porcien type (Oxfordian) or the Savonnières type (Tithonian) are also observed, showing transport from opposite directions (from the north-east and the south-east). And to the south, the most significant influence seems to be the import of stones from the Morvan border. These supplies are in addition to the use of local resources for rough stone or the import of extra-regional ornamental stones, such as that from the Palaeozoic era in the Ardennes Massif or marble and granites from the Mediterranean region.

3.2. Medieval times

Following the collapse of the Roman Empire, the use of stone and active quarries is challenging to analyze. Many buildings are constructed partially using reused stone from Gallo-Roman constructions. The distribution of sarcophagi provides evidence of the continuation or opening of new quarrying sites and distribution routes (Finoulst & Fronteau, 2022). In the north-western part of the study area, fine, homogeneous limestone from the Lutetian period seems to have been quarried specifically for this purpose, in addition to material quarried from the Middle Jurassic strata in Lorraine and the Upper Jurassic in Burgundy for standard constructions. Savonnières-type stone continues to be quarried, with significant spread to the north, but not as far as Reims.

In Reims, new supply strategies emerged during the Middle Ages, with local Lutetian limestones, such as Courville/Hermonville type stones (Turmel *et al.*, 2014), appearing and then becoming more widespread, while Lutetian limestones with facies corresponding to more distant deposits no longer seemed to be imported. In Langres, the white oolitic limestones of the Bathonian no longer reach the town but only as re-uses of antique elements. On the other hand, it is the Lower Bajocian limestones, coral limestones from Langres and crinoidal limestones of Cohons stone type that are used. Further north, Dom-le-Mesnil-type quarries developed, and their limestones were spread by the River Meuse as far north as Liège in Belgium, almost 200 km away (Lecuit *et al.*, 2018).

During this period, marked by Gothic and then Baroque monuments, the Savonnières-type oolitic limestone continued to be quarried and spread along the river Marne toward the heart of chalky Champagne (Chalons-en-Champagne, L'épine), 100 km to the north, but also 100 km to the west and the town of Troyes, where it supplanted the limestone previously imported from Burgundy to the south.

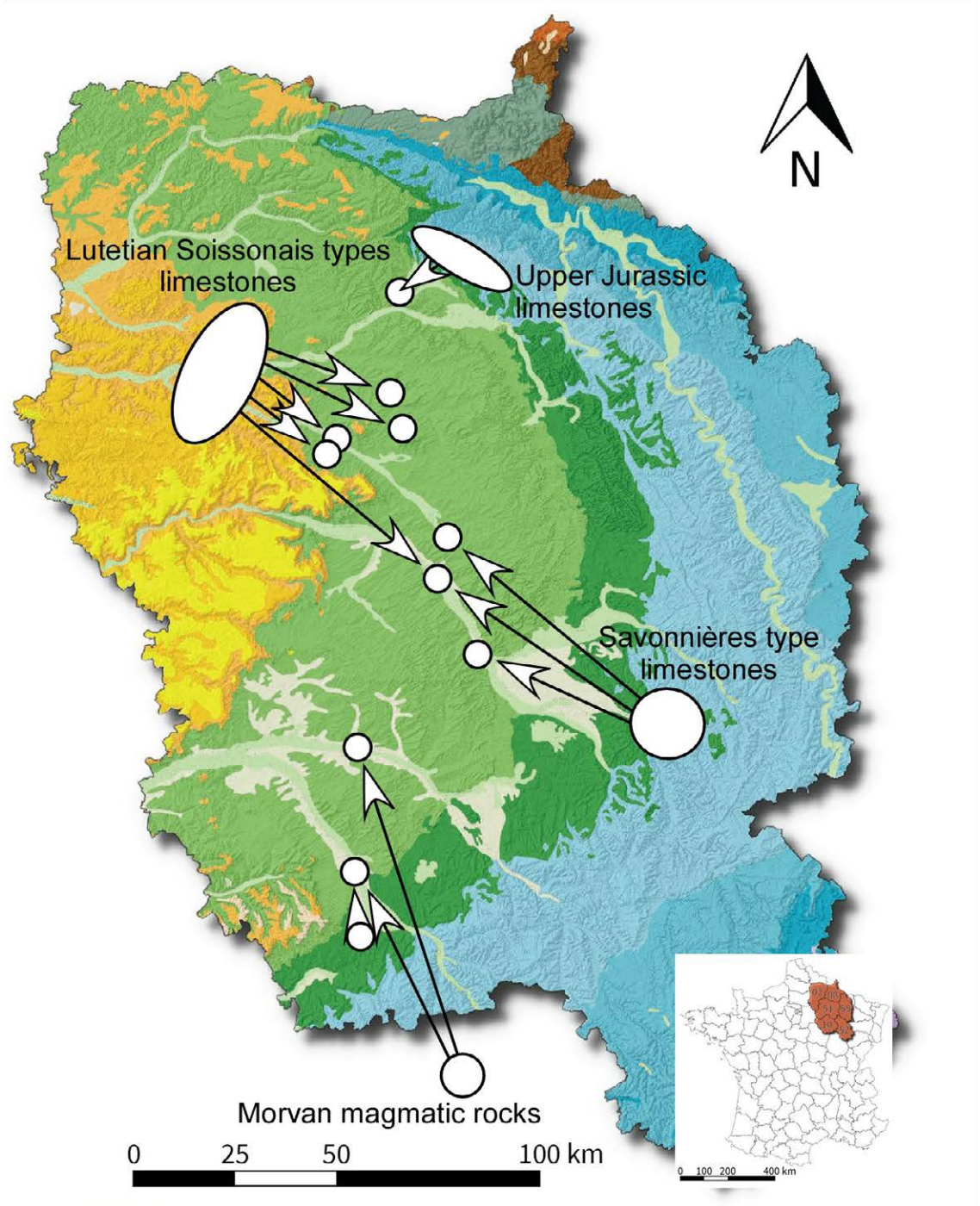


Figure 2. Some origins of the building stones used in the chalky Champagne area during Antiquity.

Figura 2. Procedencia de las piedras de construcción utilizadas en la zona cretácea de Champagne.

3.3. Modern period

French archives from before the French Revolution (1789) are challenging for geologists to explore due to their historical bias. By contrast, the works and maps produced during the 19th century are easier to interpret, especially as they contribute to the development of modern geology and the geological

time scale, which makes it easier to transpose them into current data. However, we should mention the memoirs and maps produced by J.E Guéttard between 1750 and 1780 (Guéttard, 1754; Guéttard & Monnet, 1780). Because not only this scientist adopts a distinctly modern approach to geological features and objects, but he also undertook multiple trips across north-eastern France to document the mineralogical and geological resources of the country. These journeys resulted in several publications, the majority of which were highly relevant, including an atlas containing a series of remarkable maps. However, a detailed examination of these works reveals that the data published by J.E. Guettard is highly heterogeneous. Some geographical sectors are described in detail and with a high level of accuracy, while others are only partially covered or even completely unusable. For example, the dimension stone quarries on the banks of the Meuse valley in the Dom-le-Mesnil sector are both shown on the maps, represented with a quasi-stratigraphic section and presented in the texts accompanying the atlases. In contrast, the author's approach to the numerous quarries in Lorraine, situated further upstream along the Meuse Valley, is to simply indicate that the entire region is composed of limestone. On the maps, the figures appear randomly distributed and not at the locations of the recognised stone quarries.

4. CATEGORIZATION, EXPANSION AND USAGE OF BUILDING LIMESTONES IN NORTH-EASTERN REGION OF FRANCE

The stones of north – easter region of France have been used since memorial times mainly with local expansion. However, some of them can be found in monuments and stoneworks found even hundreds of kilometers away from their source. This relays on the importance of the quarry, the stone quality and adaptability to its purpose, and of course the possibility of travel paths to transport the stones long distances from the quarries.

Establishing the exact quarry from which rocks originate is challenging due to the lack of documentation and the disappearance of old quarries, either from continued exploitation or conversion to agricultural land. Additionally, the same type of stone might have had different names depending on the quarrying area and time. Some quarries were very small and local and there could be multiple quarries with different names for their product, even though they correspond to the same facies.

Given these challenges, the most effective approach to determining the stones used in a determinate construction is to categorize them by "Stone-Type" zones. This means grouping stones with common characteristics that are extracted from adjacent areas, without always specifying the exact name given to the stone but a more general or the most extended name. These "Stone-Type" are often recognised and designated by the main quarry centre known for the considered area (Blary & Gély, 2020).

In this study, 10 distinct majors Stone-Types of various ages and locations can be identified, each with different uses and extents in construction (Figure 3). These areas were built taking into account the mention to a specific stone name in the references regarding some constructions of historical interest, but overall the similar geological period and textural characteristics of the exploitations published in 1870 (Michelot, 1870), in 1890 (Durand-Claye & Debray, 1890), and in 1970 (Noël, 1970). These works were also the basis for more recent works used in this categorization such as Fronteau (2003) and Fronteau & Lelarge (2022), information on microfacies, using Folk and Dunham classifications and porosity types, using Choquette and Pray classification (1970).

To define the expansion of the stones of this study, in order to understand the interest and propagation, that is the possibility to find it far from the quarry, we used a division built from Fronteau *et al.* (2014) who gave a classification in relation to the distance between the quarry and the monument:

- immediate area: that is the zone located within the construction perimeter.
- adjacent area: the construction is around 4 -5 Km from the quarry.
- local area: in the nearby but the quarry can be around 20 to 25 km far from the construction site (a day's journey away).

- regional area: The distance between the quarry and the construction can reach up to 90 to 100 km (around three days journey away).
- extra regional area: the stones are specially selected for a construction, and they are sent more than 100 km from their extraction site.

The ten Stone – types are listed chronologically and for some of them, their textural characterisation was summarized in Figure 4, with the textural and pore classification from Choquette & Pray (1970).

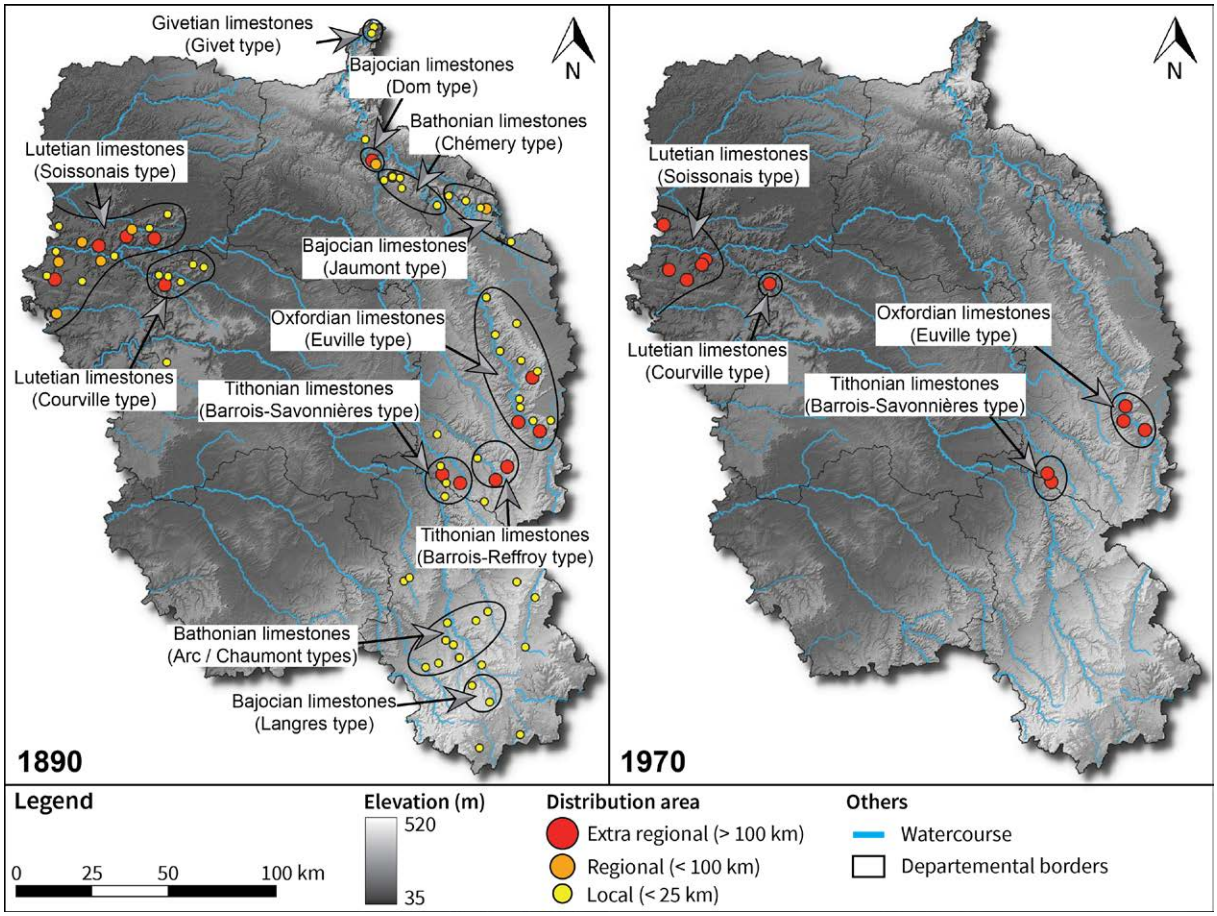


Figure 3. Distribution of quarries in the study area in 1890 and 1970, grouped by stone type.
The colors indicate the extent of their distribution and use.

Figura 3. Distribución de las canteras en la zona de estudio en 1890 y 1970, agrupadas por Piedra-Tipo.
Los colores indican el alcance de su distribución y uso.

Givetian

1. Givet Stone-Type (Figure 5.A): The limestones from Givet area, dating from the Devonian period, are quarried near the Givetian stratotype. They are characterized by massive dark stones known as “black” or “blue limestones” and are also knowned further north in Carboniferous formations (Mosan limestones from Belgium). These are recrystallized stones with low porosity and calcite veins (Figure 4). This restricted area in the north of the study region (Figure 3) had up to five quarries listed in the 1890 dataset, divided between two locations: Givet and Rancennes. Their use was primarily immediate to local, with some use dedicated to decorative elements. These stones can still be found in ancient constructions in the Ardennes and Belgium. In France, one of the quarries remains active but has been used solely for aggregates since 1998, rather than for dimensional stone.

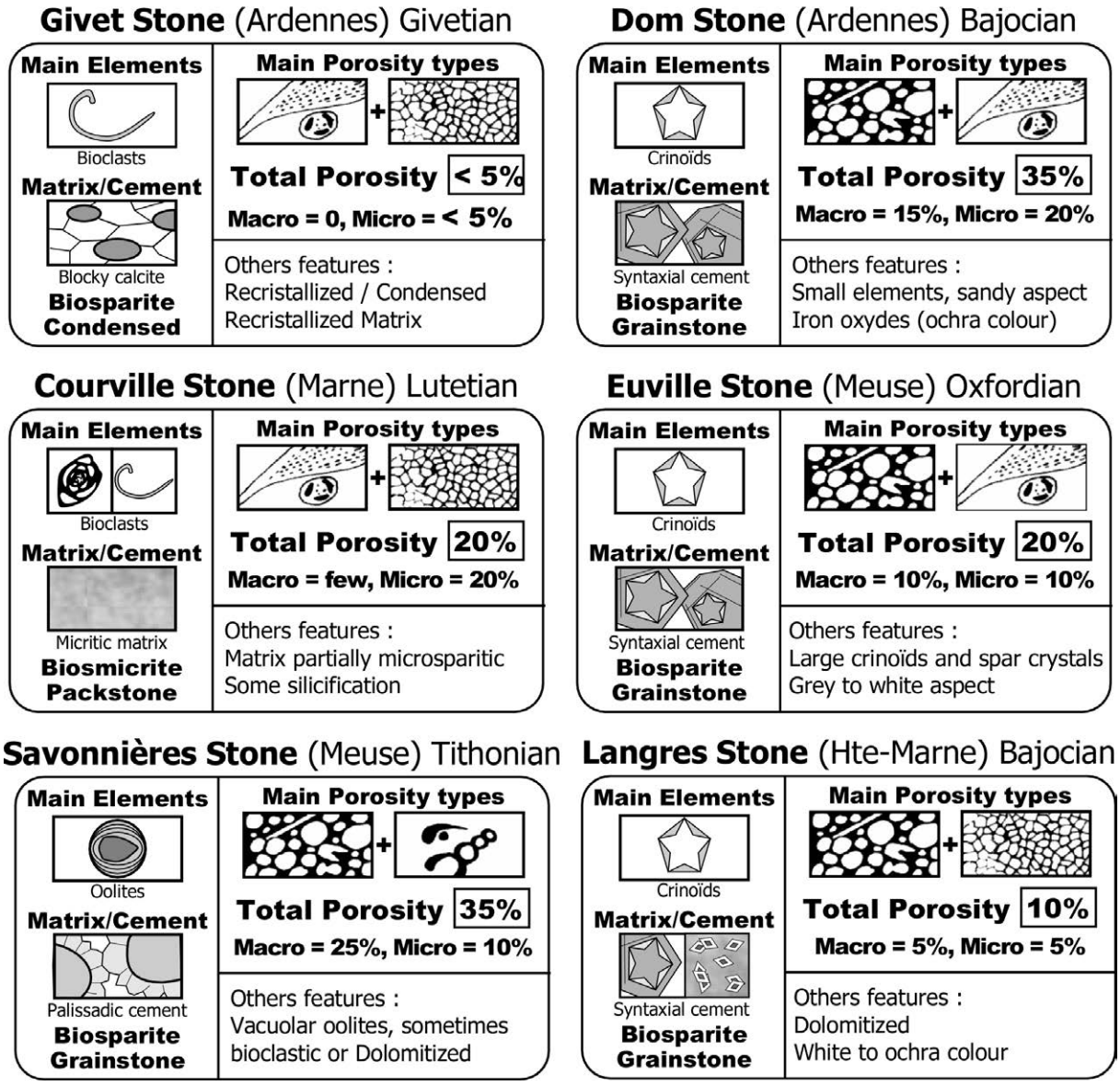
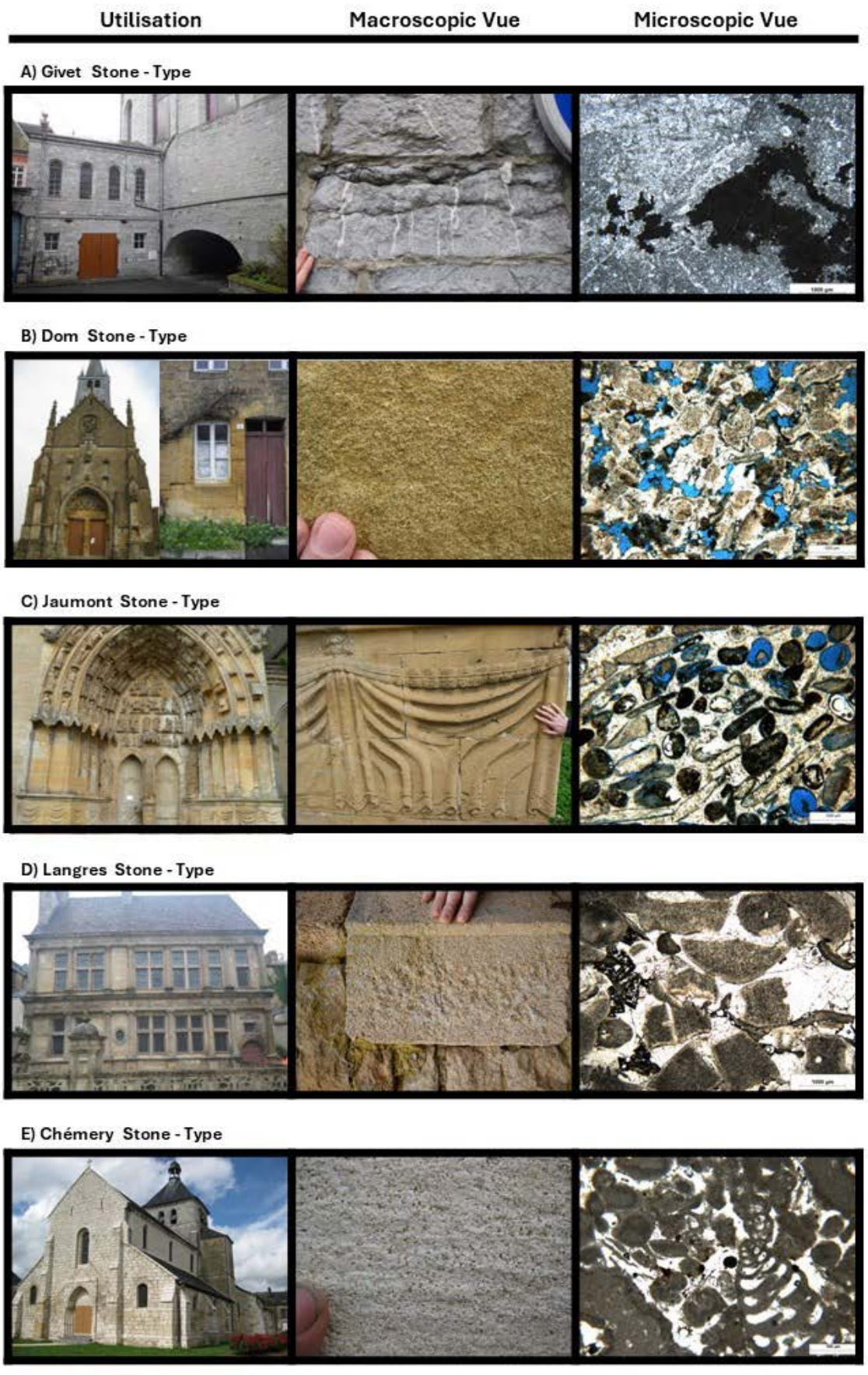


Figure 4. Schemes of the petrological features of the Stone – Types in this study.

Figura 4. Esquemas de las características petrológicas de las Piedras – Tipo de este estudio.

Bajocian

2. Dom Stone-Type (Figure 5.B): Dom-le-Mesnil limestones are bioclastic limestones, mainly very small crinoids fragments, characterized by a yellow-brownish to ochra colour due to iron oxides and visible porosity (Figure 4). These stones were quarried in the northern part of the study area (Figure 3). In the 1890 survey (Durand-Claye & Debray, 1890), three zones were listed as exploiting stones with these characteristics: Dom-le-Mesnil with eleven quarries, Hannogne-Saint-Martin with three quarries, and Haraucourt, specifically Pierre de Bulson, with one quarry. This Dom Stone-Type was already used in ancient constructions in what is now northern France and Belgium, spreading until Liège area by the Meuse river during medieval times (Lecuit *et al.*, 2018). In modern times, it was predominantly used in the fortifications of Sedan, as well as in Reims fortifications and various administrative buildings. Therefore, the expansion of this stone type can be considered one of the most widespread in regional and extra-regional areas. Although it is no longer used as dimension stone, the quarries remain active for other purposes.


Utilisation
Macroscopic Vue
Microscopic Vue
A) Givet Stone - Type
B) Dom Stone - Type
C) Jaumont Stone - Type
D) Langres Stone - Type
E) Chémery Stone - Type

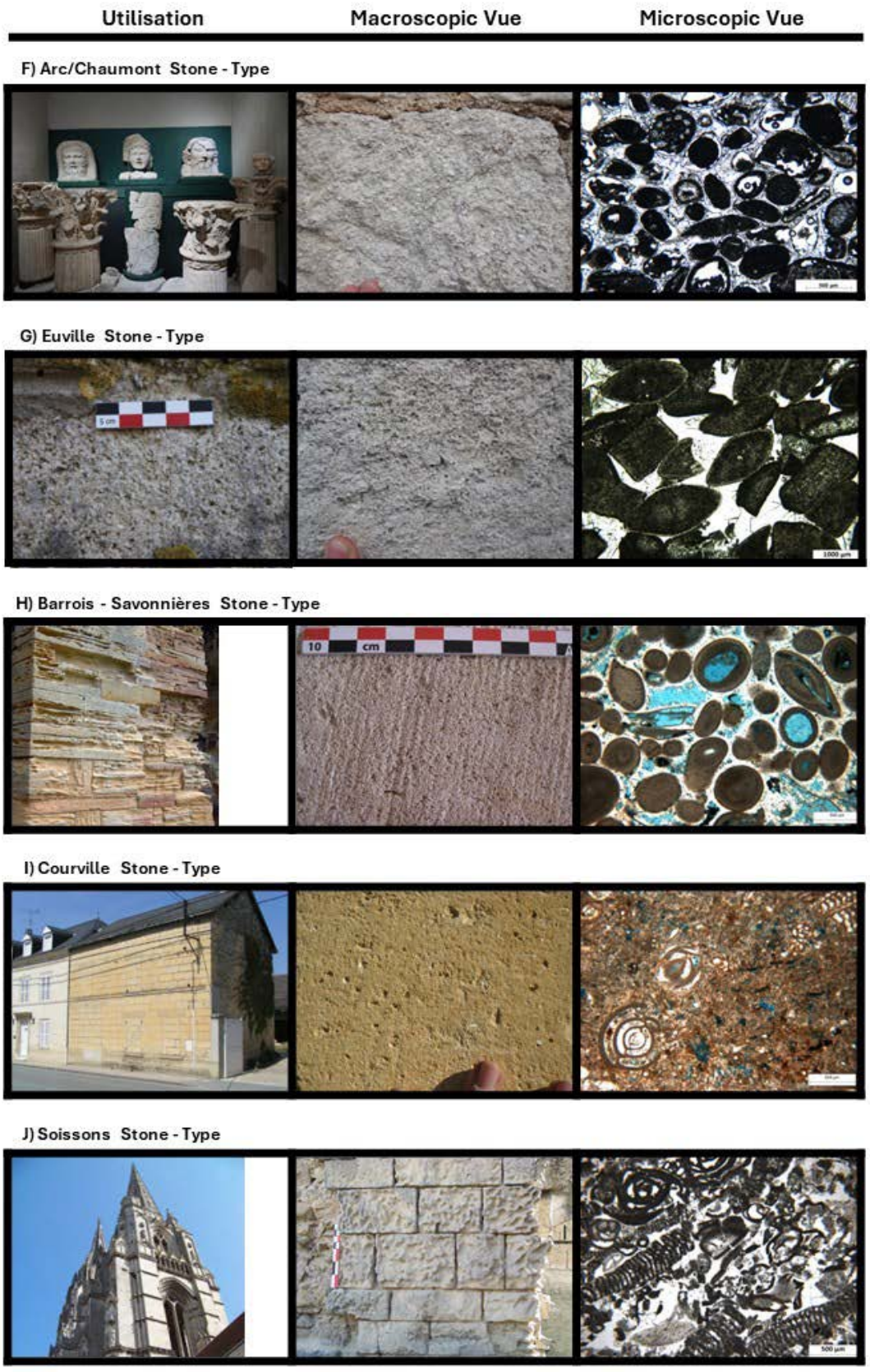


Figure 5. Photographs of each Stone – Type including examples of their use, a macroscopic image and a microscopic image obtained by polarizing microscopy.

Figura 5. Fotografías de cada Piedra – Tipo con ejemplos de su utilización, una imagen macroscópica y una imagen vista con el microscopio de polarización.

3. Jaumont Stone-Type (Figure 5.C): The Jaumont stone is an oolitic limestone with few non-oolitised bioclasts, characterized by its golden color. The main quarries within the study zone are located in the current Meuse department, in the northeast region shown in Figure 3, although the most significant sites of exploitation are situated in the adjacent department, which is not included in this study. In our research, five stones with similar characteristics but different names, exploited in seven quarries, were catalogued in the 1890 report, whereas in 1970, none of these quarries were active. Notably, the Pierre of Montmédy, which exploited Jaumont stone-type in three quarries, is worth mentioning. Jaumont Stone–Type has been primarily used for regional purposes since ancient times. For example, it can be found in the Metz Cathedral and in monuments in present-day Belgium from the Roman era, indicating its exploitation for around 2000 years, and its transport over long extra-regional distances (Coquelet *et al.*, 2013).

4. Langres Stone-Type (Figure 5.D): These limestones are characterized by the presence of crinoids and crinoid fragments in a calcitic to ferruginous matrix in varying proportions (Figure 4). Guettard (1754), described these stones as being formed by crinoid fragments with a matrix of different colors. Although there is no information about their exploitation before the documents of Peuchet & Chanlaire (1811), which show the existence of three quarrying zones for this type of stone (Cohons, Noidant and Verseilles). In 1890, four zones with stones of similar characteristics were defined (Pierre de Cohons, Pierre de Grenant, Pierre de Fontaine-au-Bassin, and Pierre de Rolampont), with more than 12 quarries in total. However, the database from 1970 did not show any active quarries at that time (Figure 3). Currently, the Fontaine-au-Bassin quarry at Saint-Cierges supplies the blocks used for restoring the built heritage of this area. Indeed, these limestones were used locally, forming most of the monuments and ancient buildings in the town of Langres and its surroundings.

Bathonian

5. Chémery Stone–Type (Figure 5.E): In the north of the study area, near the Dom and Jaumont stone types, there is a with stone-type limestone that has also been exploited since Roman times. This is a white or light suboolitic limestone with fossil fragments, mainly brachiopods. A characteristic feature of this stone is the heterogeneity of facies within a single quarry or exploitation area, but homogeneity among different quarries. This Stone-Type is found throughout the northern part of the current Ardennes department, extending approximately 60 km (Fronteau & Lelarge, 2022). The quarries considered the standard for the Chémery Stone - Type are located in Chémery-sur-Bar, with two quarries. However, other stones, such as the Pierre du Fond de l'Enfer in Bulson can also be included in this Stone- Type, with three quarries. In the 1970 dataset, these quarries no longer appeared (Figure 3), now this stone-type is quarried only for rockfilling and not for dimensional stone. The Chémery Stone-Type was found in Roman and post-Roman period stoneworks in present-day Belgium (Coquelet *et al.*, 2013, Finoulst & Fronteau, 2022), demonstrating its regional significance. In modern times, its use has been primarily local.

6. Arc/Chaumont Stone – Type (Figure 5.F): In the south of the study area, a zone with several small quarries can be defined (Figure 3). The Stone-Type is a white oolitic limestone, with slight differences in oolite size and the presence of nodules. This stone is mainly located in the Arc-en-Barrois area and takes its name from there. Historical documents indicate that its use was primarily local. Very close limestone, that we link to the Arc Stone-Type, probably quarried 15 kilometers toward the east of Langres, are observed in the roman antique monuments of this city. By the late 1800s, up to six exploitation zones were identified, each with its own name for the stone, ranging from 2 quarries for Villiers-sur-Suize, and up to 7 and 13 quarries for Crénay-sur-Suize and Prauthoy respectively. Additionally, there is the Chaumont stone type, a fine creamy limestone with a similar color but without oolites. In the Chaumont area, eleven quarries were found, also serving a local economic area. Later studies revealed the disappearance of all these quarries (Figure 3).

Oxfordian

7. Euville Stone – Type (Figure 5.G): This grey to whitish limestone is characterized by large crinoids ossicles and linked by spar syntaxial calcite (Figure 4). Among the Stone - Types examined in this study, the Euville Stone-Type stands out with the largest number of quarries and includes some well-known stones. For instance, an 1870 database listed four quarries near the village of Euville and Mécrin and thirteen in Lerouville. These sources are considered the same stone type due to their similar features. Additionally, stones quarried in Ambly (three quarries), Vignot (two quarries), Chaillon, and Senonville also fall into this category. In just twenty years, most zones with isolated quarries or two quarries saw them disappear. While the four quarries in Euville remained active, Lerouville's thirteen quarries were reduced to six, and Mécrin's four quarries were reduced to one. Contrary to other exploitation zones mentioned in this work, this stone type remains actively quarried, as documented by Noël (1970), which mentions quarries in Euville, Lerouville, and Mécrin (Figure 3). This Stone–Type has been found in Roman-period stoneworks in present-day Belgium, the Netherlands, and Germany, far from its extraction sites. The Euville stone type has also adorned significant Parisian monuments, including the Louvre, the Opera, and the Notre-Dame bridges. This stone was also used in numerous European cities, including churches in Essen, Brussels University, Antwerp Cathedral, and other monuments in Ghent and Bruges, showcasing its widespread acclaim.

Tithonian

8. Barrois oolithe Stone–Type (Figure 5.H). These stones are described as oolitic whitish to grey or yellow limestones found in the eastern part of the study area (Lehrberger & von Plehwe-Leisen, 2015). Among this type, Savonnières and Reffroy limestones are particularly notable and known by their name individually, due to their extensive use in distant locations. Their quarries are relatively close to each other (20 km) and their differences in texture are minor. But these differences are significant for specialists (geologists or stonecutters), with Savonnières group being vacuolar and easy to cut or to sawn, sometimes categorized as "Royal banc", while Reffroy group characterized by deformed oolits, stronger, with less porosity (Figure 4). The history of these quarries is more complex than that of other stone types. The Savonnières is observed in few gallic sculptures (before the roman conquest), largely used during antique, early-medieval and gothic or tardi-medieval times. The database published in 1870 (Michelot, 1870) listed a large number of quarries for this stone type, which drastically declined by 1889 (Durand-Claye & Debray, 1890) but some of them, still exists until nowadays and were re-exploited after the 19th century. For example, near the village of Savonnières-en-Perthois, up to twenty-five quarries were recorded in 1870, but only three remained in the 1890 catalogue (Durand-Claye & Debray, 1890). Reffroy stone showed similar trends, with seven quarries in 1870 and none in 1890. In Brauvilliers, a village near Savonnières, the number of quarries decreased from fourteen in 1870 to one in 1890. Nearly twenty other small quarries of this stone type documented in 1870 had completely disappeared twenty years later. However, more recent data from 1970 indicated around eleven quarries in Brauvilliers and Savonnières area, distinguishing the stone types in this case (Figure 3). Historically, the Barrois Stone-Type was used mainly locally to regionally with limited evidence of use in distant locations during antiquity or the Roman period. However, during the Upper Medieval times, the use of Lorraine stones like Norroy or Dom declined, and Savonnières stone began to spread across northern territories. The Barrois stone type was used in significant Parisian ecclesiastic buildings, Reims train station, and internationally in the Amsterdam Museum, Belgium's Royal Atheneum, and German palaces, highlighting the high demand and prestige of these stones. Savonnières stone is still a famous dimensional stone with an international use.

   In addition, the spread of Savonnières stone appears to have been early (Antiquity) and extensive to the west, where these rocks have been found as far as Châlons-en-Champagne and Troyes, around 70-80 kilometers from the quarries in numerous monuments or archaeological

sites. This can be explained by two factors: firstly, the total absence of stones suitable for the production of large, dimensional blocks in the chalky Champagne micro-region; secondly, the presence of the river Marne, a navigable watercourse flowing downstream from the quarries towards Champagne.

Lutetian

9. Courville Stone-Type (Figure 5.I): This is a fine micritic limestone ranging from white to russet, containing fossils such as mollusc shells, foraminifera, and green algae (Figure 4) (Fronteau *et al.*, 2010). This Stone-Type was extracted from numerous sites within approximately 20 km of the Reims area (Devos *et al.*, 2010, Turmel *et al.*, 2016). In Reims, new supply strategies emerged during the Middle Ages, utilizing local Lutetian limestones like the Courville type (Trigny or Hermonville area) instead of importing Lutetian stones from farther quarries (Soissonais stone-types) that, gradually became more widespread. According to bibliography from 1890 (Durand-Claye & Debray, 1890), at least six exploitation areas were identified, with one or two quarries each, as Courville that gives the name to the stone – type or Hermonville very common in regional constructions (Figure 3). One quarry at the Courville site remained active until 2000, supplying material for the restoration of Reims Cathedral. These quarries provided stone for many constructions, including Reims Cathedral and the Basilica of Saint Remi. The stone was also exported to Paris, where it can be found in locations such as Saint Lazare Station, and further afield to other extra-regional sites such as the Hotel de Ville in Brussels.

10. Soissons Stone-Type (Figure 5.J): In the Soissons area, Lutetian limestones range from white to creamy in colour, primarily featuring a fine grain and often containing miliolids or shells. When focusing our study on the Soissons area rather than the current Aisne department, we observe that these limestones were extracted from numerous quarries, each giving the stones slightly different names despite their similar characteristics. Over ten different stones were extracted from one, two, or at most three quarries, even though they belong to the same type with minor differences. A 1970 document revealed the evolution of some quarries, including the disappearance of some, the merging of others, and the opening of new ones (Figure 3). By 1970, six types of stones could be categorized under the name “Soissons Stone - Type.” The Pierre de Billy, Pierre de Charentigny, Pierre de Noyant, and Pierre de Vierzy are characterized by an abundant macro-porosity and the presence of miliolids. They were used locally as well as in significant regional monuments in Paris and Reims. Saint Pierre Aigle stone, which contains shells, was widely used from 1854 onwards in the restoration of the Château de Pierrefonds, and in the early 1900s in the Chartres Cathedral and Notre Dame de Paris. The final stone in this group is Vassens stone, which lacks bioclasts but maintains a soft white appearance, and was used both regionally and beyond in Paris, Reims, Amiens, and Rouen, among other locations.

5. CONCLUSION

The study of quarries reveals significant insights into historical and modern stone extraction and use. Two main conclusions can be drawn from this study.

1. Information from ancient quarrying times is often scarce and inaccurate, while modern documents can be confusing due to the numerous names and quarries associated with the same or similar rock facies. Therefore, when the exact origin of a stone used in a monument or construction is unknown, it is advisable to use stone-type names that provide more general characteristics and locations to avoid errors. It is essential to standardize the classification of dimensional stones, considering their age and characteristics.

2. This study highlights a significant decrease in the number of quarries since the end of the XIX century. In 1870 and 1890 many small quarries were listed as active exploitations, but over time, a large number have disappeared, leaving only a few active in 1970 in areas such

as Savonnières, Soissons, and Euville. These remaining quarries supply stone for current construction projects and the restoration of ancient monuments in the area. But the shortage of stone and the quite disappearance of dimensional stone quarries in the north of France is now a major problem for restoration work leading to imports of building materials from other regions and even other countries.

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Theo Krauffel: Investigation, Methodology, Writing – original draft, Writing – review & editing.

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