The Database of the Ornamental Stones of Piemonte (NW Italy) Hosted on a WebGIS Service

UNIVERSITÀ DEGLI STUDI DI TORINO

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Abstract:	In Piemonte (north-western Italy), an intense extraction activity of ornamental stones widely used for historical buildings, developed throughout centuries. This is due to the wide geodiversity of the region, characterised by mostly metamorphic and magmatic rocks in the Western Alps and by terrigenous and carbonate sedimentary rocks in the Alps-Apennines syn-orogenic basins. The work presents the description and classification of the main Piemonte ornamental stones, referring to a simplified lithological Map Legend. To enhance the remarkable historical and contemporary stone heritage of the region a database (DB) was developed addressing a proper cataloguing of the ornamental stones and related quarries. The classified instances have been referred to the geologic units of a

	regional-scale, interactive geological map, in which each ornamental stone was attributed to few geo-lithological classes. The map was developed as a WebGIS service hosted on a geoportal (https://webgis.arpa.piemonte.it/agportal/apps/webappviewer/index.html?id=6ea1e38603d6469298333c2efbc76c72) that allows interactive querying and download of the DB information, regarding the main rock types and the corresponding quarries, as well as their historical-architectural uses, to underline their value as witness of cultural heritage. The WebGIS service is progressively fed by new data, in order to become a relevant source of information for those working in the field of cultural heritage and geo-environmental sciences.
Response to Reviewers:	Rebuttal letter The Database of the ornamental stones of Piemonte (NW Italy) hosted in a WebGIS service by Elena Storta Dear Editor, We would like to thank the reviewers for their comments on our submitted manuscript “The DataBase of the ornamental stones of Piemonte (NW Italy) hosted in a WebGIS Service”. Following their suggestions, we revised our original manuscript making it more robust and convincing. We responded to all the comments and updated the text accordingly. The main changes to the manuscript are in agreement with the reviewers suggestions, as recommended. Below you will find our systematic replies to the reviewer comments. We hope that you’ll accept this new version of the manuscript for publication. Kind regards. Elena Storta, On behalf of the co-authors Reviewer #1 comments: Note: Our comments are in Italic with indentation, in the response to the Reviewer; the line numbers refer to the first pdf version; we also accepted the suggested changes to the text. First of all, the manuscript does not conform to the format of the Geoheritage journal. The Geoheritage format must be strictly followed. Please do not just use ‘italics’ for the expressions in your native language, but an ‘in italian’ indicating that it is in Italian. No one will know your native language or be able to easily understand your explanations in English. We changed according to the Journal rules and in agreement with the reviewer. Abstract The Abstract is not very adequately prepared to convey the essence of this work. The choice of words and their usage (upper and lower case) is not appropriate. The general usage of this subject should be looked up in the literature. This section should be reorganised. Following your suggentions we have partially rewritten the Abstract. As regards upper and lower case of words, the geological map is called “Carta Geolitologica delle Pietre ornamentali del Piemonte” (in English Geolithological Map of the ornamental Stones of Piemonte) with capital letters, in agreement with CNR-IGG Torino, ARPA Piemonte

	and University of Torino. 1. Line 19: This website cannot be reached. Why is an inactive link included? (https://webgis.arpa.piemonte.it/agportal/apps/webappviewer/index.html?id=6ea1e38603d6469298333c2efbc76c72) We apologize for the inconvenience: There have been problems with the CSI (Consorzio per il Sistema Informativo del Piemonte) directives, in particular, for technical reasons, on the ARPA Piemonte (Co-Authors of the article) server there have been problems in publishing the WebGIS link accompanied by the geological cartography on which the Ornamental Stones Database is based (the problem was that only in certain European countries the link did not work due to security problems). The problem should have been solved and we hope that the link is also visible in your country. 2. Line 23: ...Cultural Heritage... Why this use? We corrected it. 3. Line 24: The present paper describes... The meaning of a word like 'paper' in the manuscript is not appropriate. Here it could be study, work, research and present. Please avoid the use of paper. We have changed to a more appropriate term. 4. Line 27: The words in the Keywords must also be included in the Abstract. All the Keywords are included in the abstract. On Line 15 of the introduction we changed stone materials to ornamental stones. 1. Introduction The main problem with this chapter is that a country like Italy has produced a vast amount of literature on both famous sculpture and natural stone. The Introduction should include some of the thousands of publications from the country that has produced Travertine (Travertine, Allan Pentecost, https://doi.org/10.1007/1-4020-3606-X), such as this Travertine book, and some key references, such as those found in Geoheritage journal. This section is very poorly organised. Basically, the 'Introduction' should be divided into three parts. 1. Introduction: Entrance of the basic literature in connection with your topic. 2. Development: Elaboration of the topic 'ornamental stones' and 'WebGIS' and supporting it with literature. 3. Conclusion: The impact, contribution and difference of the presentation of 'ornamental stones' and 'WebGIS' topics via 'DataBase' should be given. We have modified the introduction by integrating with further bibliography. We believe that, since these are Piemonte ornamental stones, it is not necessary to include bibliography that deals with ornamental stones from other Italian regions as Travertine, which was never mentioned in our work. Also following the observations of the Reviewer #2, we have however increased the citations relating to the use of ornamental stones in the field of cultural heritage. Where abbreviations are given for the first time in this section, you should give the long and clear form. We corrected it. 1. Line 54: 'The GeoPiemonte Map was developed by CNR'. What CNR mean here? We corrected it. 2. The geological diversity of Piemonte Since the general geological features in this section are based on the main theme of stones; only the map in Fig. 1 is not sufficient. More comprehensive and detailed geological information and a very comprehensive stratigraphic column section of Piemonte should be given. We have rewritten chapter 2 entirely, with a very detailed geological setting of Piemonte. We have also enriched it with a further figure of a more explanatory geological map. However, we believe that it is not possible to include a stratigraphic column from Piemonte, since the ornamental stones of the region are of both magmatic, sedimentary and metamorphic origin. Furthermore, it is impossible to define a single stratigraphic column for the many and very different sedimentary successions that exist throughout Piemonte, that were deposited in independent basins developed in completely different times and geodynamic contexts (Late Paleozoic to Cretaceous extensional regime, Paleocene-Pliocene compressional one). Rather, a detailed geological framework of the geology of Piemonte has been reported, making reference to the bibliography produced in the last 100 years, integrated with a new geological scheme (Fig. 1) which summarizes and highlights the complex geological evolution.

	Line 81: The explanations in Fig. 1 should be checked by a senior geologist. It is also mandatory to mark the N direction on the maps. For Fig.1, you need to get help from a person who is an expert in the subject. We have modified Fig.1 (now Fig.2) according to your advice, but above all following the comments of reviewer #2. The geological setting is now implemented and integrated with a further figure showing the great paleogeographic complexity of Piemonte (Fig.1). Line 86-93: The definitions written here cannot be explained in this way. The expressions 'terrigenous and allo/orthochemical rocks', 'plutonic and volcanic rocks', 'marbles, gneisses', 'mafic/ultramafic rocks', and 'other metamorphic rocks' are very specific. Since you did not define them, you should avoid unattributed descriptions as each topic requires different expertise. We have integrated the terminology by defining each classification used. We also assume that the geoheritage readers have at least a basic knowledge in Geology; the classification of the rocks we use is at the simplest level of distinguishing great categories according to their genesis (magmatic, sedimentary etc.). 3. Historical Piemonte ornamental stones and their use The most effective figures and descriptions related to your main theme is a very inadequate point. The rock representation in Fig. 2, the text on the photo and the photo dimensions are not at a level to be published. Separate figures should be produced by separating the rock groups here according to their origins. For example; 3.1 Sedimentary rocks, 3.2 Magmatic rocks, 3.3 Metamorphic rocks for selected specimens should be grouped separately. Larger scale photographs should be included here. We have modified according to your advice; now the rocks and their relative figures are separated and reorganized into main groups. The photographs have also been improved and reported in larger dimensions. In a very important deficiency, the inclusion of thin sections of each rock type in such a study would strengthen the scientific basis of the study and make a significant contribution to the literature. Fig. 2 cannot be defined only with macro samples. There are also features that should be given on thin sections. For the known ornamental stones, the thin section study has already been done and is the subject of several papers. Furthermore, the thin section study and consequently the minero-petrographic characterization of each rock is the subject of a PhD thesis and will be published in other scientific works. We believe that due to the scope of the work and the purpose of the research, it is not necessary to include a detailed study. Furthermore, the DB does not include the thin section study, only the macroscopic description. Fig. 3 and Fig. 4 should be given with a more detailed and accurate/professional photography technique. The photography of these art historical buildings should at least be done with a correct perspective. More care should be taken when introducing the most important buildings of your country in an SCI journal. We have modified it by changing photographs with a more adequate perspective. Line 96: ...Legend of Fig. 1... writing rules should be observed. We have modifed. Line 121-125: ....macrophoraminifera (Amphistegina, Miogypsina)... pay attention here, both the fossil genus writing and the description. These benthic foraminifera are the subject of micropaleontology. There is no such term as Macroforaminifera. Smaller or Larger Benthic Foraminifera are used. Correct writing: Larger Benthic Foraminifera (Amphistegina and Miogypsina) or... Amphistegina and Miogypsina of LBF genus... Done. Line 164: ...early Permian age...The use of 'early' is informal and not a correct expression. For detailed information, please see 'https://stratigraphy.org/chart#latest-version'. Modified. Line 351-352: "The main constituents are quartz, phengite, omphacite, garnet and epidote while titanite, apatite and zircon are present in accessory quantities (Sandrone et al. 2004)."

For the rocks in Fig. 2, of which you present macro-samples as well as the reference you cite in this sentence, it is necessary to have thin sections and to identify them.
We have modified, leaving a short macroscopic description.
Line 406-415: This section is meaningless in this way. It should be given as a different concept or additional document.
We do not understand which is the request. This paragraph simply shows which is the structure of DB. In any case, we have rewritten and rephrased this paragraph to make it clearer and more understandable.

5. The Interactive Geolithological Map of ornamental Stones of Piemonte (WebGIS service)
This section should be rewritten. Tables should be made before the figures, including all the propositions you have made for Fig. 5, citing them correctly, giving evidence and uncomplicated expressions. Afterwards, the website flow should be explained with figures. Since you set up the website, your statements remain very closed and cannot be understood.
We have rewritten the chapter to make it more understandable.
The list in Supplementary Material_Table 1 should be included in the text and explained.
We believe that, since they are supplementary materials, it is not necessary to insert the information contained within the section into the text.
Fig. 6 has no meaning without very detailed geological information, including stratigraphic column section and Supplementary Material_Table 1 in the text. The geological literature of the classifications in Fig. 6 should also be consulted.
We have modified the figure making it more understandable; for the reasons stated above we believe that it is not possible to insert a stratigraphic column, nor the information contained in the supplementary material. Fig. 6 (now Fig. 10) has been modified and is in agreement with the countless geological literature regarding the Piedmont region. We believe that Table 1 is best as supplementary materials, also given its size. However, we leave the final decision to the Editor.
As an example;
Fig. 6a. ‘mafic-ultramafic?’ is not a lithological classification.
Fig. 6b. ‘silicic’ and ‘siliciclastic’ are very objectionable. ‘Siliciclastic’ is a name given to a type of sedimentary rock whose formation is entirely due to mechanical effects.
Fig. 6c. ‘volcanic’? Is not your title ‘3.2.2 Volcanic rocks’ related to volcanic rocks?
Fig. 6d. transitional environments? The environments given about the origin are very wrong, some of the rocks you mention in the text cannot form in these two environments.
The figure has been modified and the terms are according to the various classification of rocks and literature, as now explained in Chapter 2.

6. Conclusions
Due to the deficiencies in the above 5 chapters, this conclusion is not appropriate in terms of both subject and scope. Here, my suggestion would be to write the conclusion again after reorganising the previous chapters.
Modified, rephrased and implemented.
Reviewer #2 comments:
Note: Our comments are in Italic with indentation, in the response to the Reviewer; relevant the line numbers refer to the first pdf version; we also accepted the suggested changes to the text.

Dear authors,

Your paper is very interesting and useful. It could serve as a good practice for other natural stones areas. However, before the paper is published, you should correct some minor flaws:
- The paper is focus on heritage. Preservation and use the correct natural stone. However, and because the first part (Introduction) is a sort of review, many previous works should be recognized. Since the creation of the Heritage Stones IUGS working group in 2013, many papers have explained the need of proper characterization of stones, the main and ultimate goal of your paper. You mention in the references Cooper (2015), but before that, and at the same time, other papers sent a call for the need of stone recognition: 10.18814/epiiugs/2013/v36i1/002
Thanks for the useful advice, we have integrated it with the works you recommended

	and with other bibliography. - It would be important to mention the international importance of the Piemonte area stones. Many monuments have used some of them. Also, artists used some of those stones during the XIX and XX centuries to build their work and now it is shown in art museums: https://doi.org/10.1007/s12371-017-0265-9 Done. - Figure 1 is very illustrative. However, the legends you have used should be more helpful in distinguishing the different lithologies. Change the legend of the small square at the bottom right to match the legend of the map (e.g., marble: purple/blue) and explain some vague terms: "stone"??? We modified the legend and followed your instructions. To make the figure easier to read, we decided to unify the two legends, eliminating the commercial classification of the ornamental stones that was present in the legend at the bottom right. - In Figure 2: Is this your own figure? Did you make the selection? If so, explain in the figure caption. But also try to select a better representative. For example, serpentinite del Favaro does not look like a serpentinite at all! Yes, we have made a selection of the main ornamental stones of Piedmont, but as recommended by reviewer #1 We have separated the photographs according to the subchapters. For simplicity, the Favaro serpentinite has been eliminated in the figure, and also in the text. - 3.3.3 Mafic/ultramafic rocks. With this caption, one would expect a long list of examples, but the main lithology here is serpentinite. Therefore, move serpentinites to the Metamorphic rocks caption, as serpentinite is a metamorphic rock. Leave the others, may be, for the Other metamorphic rocks, or Other rocks in general. We have directly changed the title of the chapter to "serpentinite and metabasites" but we have kept this subchapter, because rocks of this type in Piedmont are numerous and widely used as ornamental stones. (see division in fig. 2). - As this is a good practice, I would add at the end (Conclusions?) that the database could be part of a wider tool for natural stones around the world. We have integrated the conclusions with your advice. Finally, your paper is badly written. The English is very poor. To be able of publishing this paper in an international journal you should use professional help to polish the language. Otherwise, congratulations for the great effort. Done.

Title: The Database of the ornamental stones of Piemonte (NW Italy) hosted on a WebGIS service

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Abstract:

In Piemonte (north-western Italy), an intense extraction activity of ornamental stones widely used for historical buildings, developed throughout centuries. This is due to the wide geodiversity of the region, characterised by mostly metamorphic and magmatic rocks in the Western Alps and by terrigenous and carbonate sedimentary rocks in the Alps-Apennines syn-orogenic basins.

The work presents the description and classification of the main Piemonte ornamental stones, referring to a simplified lithological Map Legend. To enhance the remarkable historical and contemporary stone heritage of the region a database (DB) was developed addressing a proper cataloguing of the ornamental stones and related quarries. The classified instances have been referred to the geologic units of a regional-scale, interactive geological map, in which each ornamental stone was attributed to few geo-lithological classes.

The map was developed as a WebGIS service hosted on a geoportal (https://webgis.arpa.piemonte.it/agportal/apps/webappviewer/index.html?id=6ea1e38603d6469298333c2efbc76c72) that allows interactive querying and download of the DB information, regarding the main rock types and the corresponding quarries, as well as their historical-architectural uses, to underline their value as witness of cultural heritage. The WebGIS service is progressively fed by new data, in order to become a relevant source of information for those working in the field of cultural heritage and geo-environmental sciences.

Keywords: Ornamental stones, Geological map, Database, Quarries, Piemonte, WebGIS service

1. Introduction

Stone has always represented one of the main sources of material in the construction industry and, in particular, an important cultural element as it is used as raw material in the field of sculpture and architecture, which is now part of the

cultural heritage of humanity (Borghi et al. 2014; Brocx and Semeniuk 2019). Therefore, the knowledge of stone resources, their minero-petrographic characteristics and their use from Antiquity to the Present can provide a broad historical and cultural panorama of these materials, underlining the importance of a very relevant economic activity in the history and traditions of the different cultures (Cooper 2015). Indeed, the scientific knowledge (location of the quarries, geological features, petrographic composition, historic use and heritage utilisation and related heritage issues of stones) of some important ornamental stones designed as "Global Heritage Stone Resource" (GHSR), would generally lead to a greater awareness of the importance of stone as a common good and therefore to their recognition by national and international authorities (Cooper et al. 2013). From the time of the ancient Greeks and Romans, natural stones have been used in construction, architecture and all kinds of arts due to their durability, but also to their beauty (Pensabene 1998; Lazzarini 2004). Over time, many books have been published relating to the ornamental stones from different countries such as Great Britain (Walkden 2017), Baltic states (Selonen and Suominen 2003), Germany (Ehling et al. 2021) and Egypt (Klemm and Klemm 2012). Around the beginning of the 20th century (Pereira and Marker 2016) many cities such as Helsinki and St Petersburg used ornamental stones (Bulak 2016), but also Paris and other European cities (DeWever et al. 2016). Natural stones have also been widely used for statues preserved in various museums (Pereira and Perez-Castro 2019).

Even the Italian regions are typified by buildings and monuments often made of natural stone. In particular, in Piemonte (NW Italy), stone has always been the most widely used building material, characterising the architectural identity not only of cities, but also of rural buildings widespread in the Alpine valleys. In Piemonte, stone has always been used in historic and contemporary buildings, monuments and street furniture, showing the close link that exists between the urban area and natural stone resources, and highlighting the role that stone has and had in culture and economic wealth of the region (Borghi et al. 2016).

From Roman times to the 18th century approximately, the most easily workable stone materials (such as marble and sedimentary rocks) were mainly exploited and used for valuable infrastructures and sculptures. Starting from the 19th century, thanks to the development of new technologies for quarrying and processing, also stones composed of harder silicate minerals have been progressively used as decorative elements. Currently, the façades and other architectural elements of historical buildings in Piemonte and especially in Torino, therefore, represent an open-air, petrographic collection where an attentive visitor can enjoy a feeling of both scientific and cultural character. For example, the petrographic description of ornamental stones of Torino has been the subject of several papers (e.g., Sacco 1907; Peretti 1937; Rodolico 1953; Chiari et al. 1992; Fiora et al. 2007). Recently, an updated catalogue of the most significant stone buildings of the city is reported by Borghi et al. (2014) and Gambino et al. (2019). However, there isn't currently an organic document that includes petrographic characterisation, provenance, geological framework and dissemination of Piemonte rocks. The previous approaches were limited to specific case history.

The promotion and dissemination of historical and cultural stones among a wider audience are fundamental, not only to improve general knowledge on natural resources but also to enhance the self-consciousness of the deep connection between environment and exploitation, balancing sustainability and cultural heritage (Dino et al. 2019).

Recently Piana et al. (2017a, b) drafted a complete interactive geological map of the Piemonte Region (GeoPiemonteMap Project) available as a WebGIS service. The GeoPiemonte Map was developed by the National Research Council, Institute of Geosciences and Georesources of Torino (CNR - IGG), the Regional Agency for the Protection of the Environment of

Piemonte (Agenzia Regionale per la Protezione Ambientale - Arpa Piemonte), and the University of Torino (Department of Earth Sciences). Starting from this, Barale et al. (2020) realised the geolithological map of the Piemonte ornamental stones at 1:250,000 scale with the aim to review the ornamental stone heritage of Piemonte at a regional scale. The map consists of a simplified lithological base, derived from the above cited GeoPiemonte Map, on which the ornamental stones are reported as punctual objects corresponding to their quarry sites. This new map, based on a thorough revision of the available literature and integrated with some unpublished original data, shows the location of the main quarries of historic and contemporaneous ornamental stones of the region. The stone materials, and their historical-architectural uses, are described in the map database (DB), properly designed to enhance the value of the stones in the cultural heritage.

This paper focuses on the description of the DB and the development of the map as a WebGIS service. The WebGIS service is hosted on the Arpa Piemonte geoportal and allows interactive querying and download of the DB information.

2. The geological diversity of Piemonte

The great variety of ornamental and building stones present in Piemonte is due to the extremely complex geological nature of the region. Indeed, in the Piemonte several different lithotypes can be recognised; such lithotypes characterise the western portion of the Alpine metamorphic chain and the sedimentary successions of the Tertiary Piemonte Basin (TPB) cropping out in the central-southern sector of the region.

Piemonte is a region characterised by a great geodiversity, with a notable variety of geological contexts that characterises the different orographic elements present, such as the mountain chains of the western Alps (Graian, Cottian, Maritime and Ligurian) and of the northern Apennines, the hill systems of the Langhe and Monferrato, the moraine systems at the outlet of the Alpine valleys and the large foothill fans that slope down into the Po Valley alluvial plain (Piana et al. 2017a) (Fig. 1).

This complex geo-diversity has aroused considerable interest over the last two hundred years, not only scientifically but also from a geo-touristic and socio-economic point of view. This geological complexity determines the geo-environmental constraints on the use of the territory, as well as the distribution and management of surface (stone materials) and subsoil (water and geothermal) georesources.

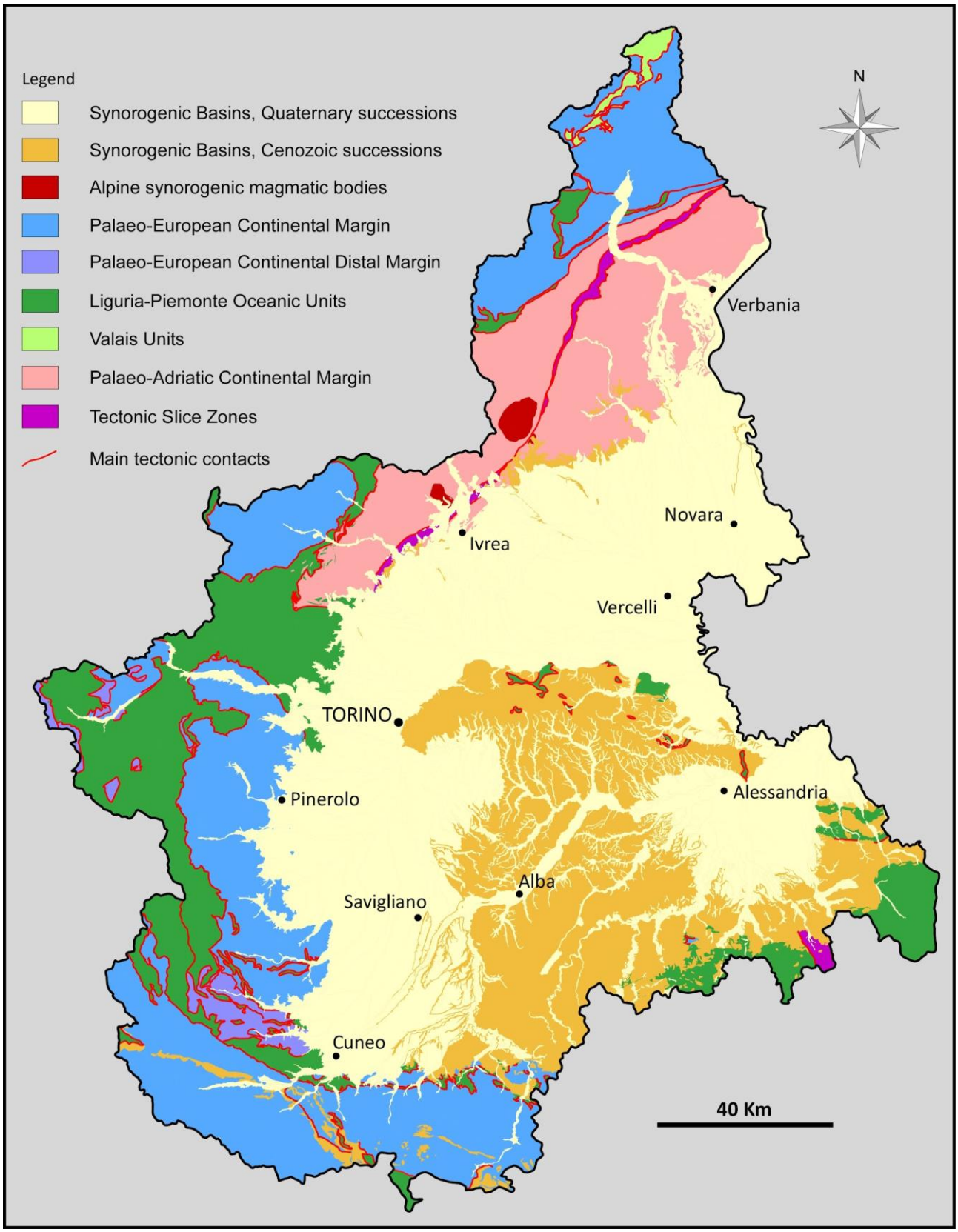

Fig. 1 Scheme showing the present distribution of the palaeogeographic domains of the Piemonte region (from Piana et al. 2017a, b)

The complexity of the geology of Piemonte is the result of a continuous geodynamic process which, since the Jurassic, led to the formation of two continental 'passive' margins: the 'Palaeo-European Continental Margin' and the 'Palaeo-Adriatic Continental Margin', and two zones of oceanic pertinence named Liguria-Piemonte Oceanic Units and Valais Units (Dal Piaz 1999; Dal Piaz et al. 1972; Dewey and Bird 1970; Dewey et al. 1973; Handy et al. 2010; Mohn et al. 2010). The 'Palaeo-European Margin' concept is here used sensu Handy et al. (2010) and Mohn et al. (2010), where the Briançonnais Domain is viewed as an isolated part of the European continental margin placed between the Valais Units and Liguria–Piemonte Oceanic Units (for the northern part of Piemonte) and a portion of the hyperextended European continental margin, named 'Palaeo-European Continental Distal Margin' (for the south-western part). The 'Palaeo-Adriatic Continental Margin' concept is here considered in the sense of Stampfli et al. (1998), referring solely to the continental margin of the 'Adriatic plate sensu stricto'. It consists of tectonic units which suffered the Alpine metamorphism under eclogite facies conditions (Sesia Lanzo Zone) or greenschist-blueschist facies conditions (Dent Blanche System) separated from the Southalpine Alpine Domain by the Insubric Line. The Palaeo-Adriatic Continental Margin was intruded in the Oligocene by the Alpine synorogenic magmatic bodies, among which two important plutons (Valle Cervo Pluton and Brosso-Traversella Pluton) and by calcalkaline volcanic suite (Biella volcano-sedimentary Suite), discordant with the main Alpine structures.

The NW Alpine chain is subdivided into three main structural domains (see Beltrando et al. 2010; Dal Piaz et al. 2003; Pfiffner et al. 1997; Schmid et al. 2004 for a review).

(i) an internal domain (Southalpine Domain) belonging to the upper plate of the collisional system (Adriatic plate) and only partially involved in the Alpine orogenic process. This domain is made of Variscan and pre-Variscan basement with middle (Serie dei Laghi Unit) and lower (Ivrea-Verbano Zone) continental crust and upper mantle rocks, which underwent minor Alpine metamorphism, intruded by Permian magmatic bodies (Permian Magmatic Complex of "Graniti dei Laghi": Mottarone-Baveno Pluton and Alzo-Roccapietra Pluton), and covered by Permian volcanic rocks, volcaniclastic deposits and a Mesozoic sedimentary succession. This domain is bounded by a Tectonic Slice Zone (Canavese Zone: ZC), a narrow, wide band a few kilometres and about 40 km long, delimited by two faults, approximately NE-SW trending, named the Internal and External Canavese Lines. The ZC consists of Permian granites and is covered by carbonate succession of Mesozoic age.

(ii) a central (axial) part of the orogenic system (partially corresponding to the Penninic Domain Auct.), bounded by two main tectonic discontinuities, the Insubric-Canavese Line on the inner side and the Penninic Front on the outer side. It is made up of rock units with different origins involved in the Alpine orogenic prism and thus metamorphosed (Beltrando et al. 2010). These units originally belonged to the Liguria-Piemonte Oceanic Units and to portions of the Palaeo-European (Briançonnais Domain, Lower and Upper Penninic Domains) and Palaeo-Adriatic (Austroalpine Domain) continental margins. The Upper Penninic Domain correspond to the so-called Internal Crystalline Massifs represented by the Monte Rosa, Gran Paradiso and Dora-Maira units, equilibrated under eclogite facies metamorphic conditions. They mainly consist of mono- and poly-metamorphic silicate-bearing rocks as micaschists and orthogneisses and minor meta-carbonate cover of Mesozoic age (e.g. De Giusti et al. 2004 and references therein). The Briançonnais Domain is further divided into an internal zone, including a polymetamorphic basement, a monometamorphic basement of Permo-Carboniferous age and a meta-sedimentary cover of Mesozoic age (Internal Briançonnais Domain) and an external zone made up of Mesozoic carbonate successions of the Palaeo-European Continental Margin (External Briançonnais Domain).

The Lower Penninic Domain represents the deepest tectonic element in the axial sector of the Alpine chain and includes the Antigorio, the Monte Leone and the Moncucco-Orselina-Isorno units.

The units of the axial sector, during their subduction at depths of 50-100 km (at approximately 65-40 Ma) and subsequent exhumation (at approximately 35-20 Ma), underwent metamorphic transformations ranging between the high and very high pressure eclogitic facies and the low-pressure, low-temperature greenschist facies.

(iii) an external domain (i.e. placed on the European side of the Alps, mostly in France and Switzerland), belonging to the lower plate of the collisional system and corresponding to the Helvetic, Dauphinois, Provençal and (partially) to the External Briançonnais domains of the geological literature. This domain consists of a Variscan polymetamorphic basement with Carboniferous to Permian sedimentary successions and intrusive bodies (Argentera Massif), Mesozoic sedimentary covers and Cenozoic synorogenic deposits, which underwent anchizone to lower greenschist facies metamorphism.

The central sector of the Piemonte region is characterised by the presence of sedimentary successions deposited, from the late Eocene to the Quaternary, in Synorogenic Basins (Cenozoic successions and Quaternary successions in Fig. 1), i.e. in basins formed during and in relation to the geodynamic conditions that led to the formation of the orogenic systems currently exposed in the Alpine and Apennine chains. These basins, which can be considered an integral part of the Alpine-Apennine orogenic system, have very well recorded the geological evolution that determined their formation. The successions of these basins, uplifted during the Cenozoic, constitute the current reliefs of the Langhe, Alto Monferrato, Monferrato and the Torino Hill. The Oligocene-Miocene succession was deposited in a basin known as Tertiary Piemonte Basin (TPB) consisting of lithostratigraphic units correlatable through the different structural domains of the TPB.

The above described subdivisions of the Alps-Apennines orogenic system inspired the Legend of the GeoPiemonte Map (Piana et al. 2017a, b) and related DB and allowed the elaboration of a new Lithological Map, reported in Barale et al. (2020), where the number of geological classes were reduced in order to have a simplified geo-lithological representation. In this work, a further simplification of the Piemonte geological Map is given (Fig. 2) to allow a concise graphic representation of the lithological variety of the region, suitable for classifying the ornamental stones, as well as a robust Data Model to be implemented by thematic data regarding cultural heritage and economic employment.

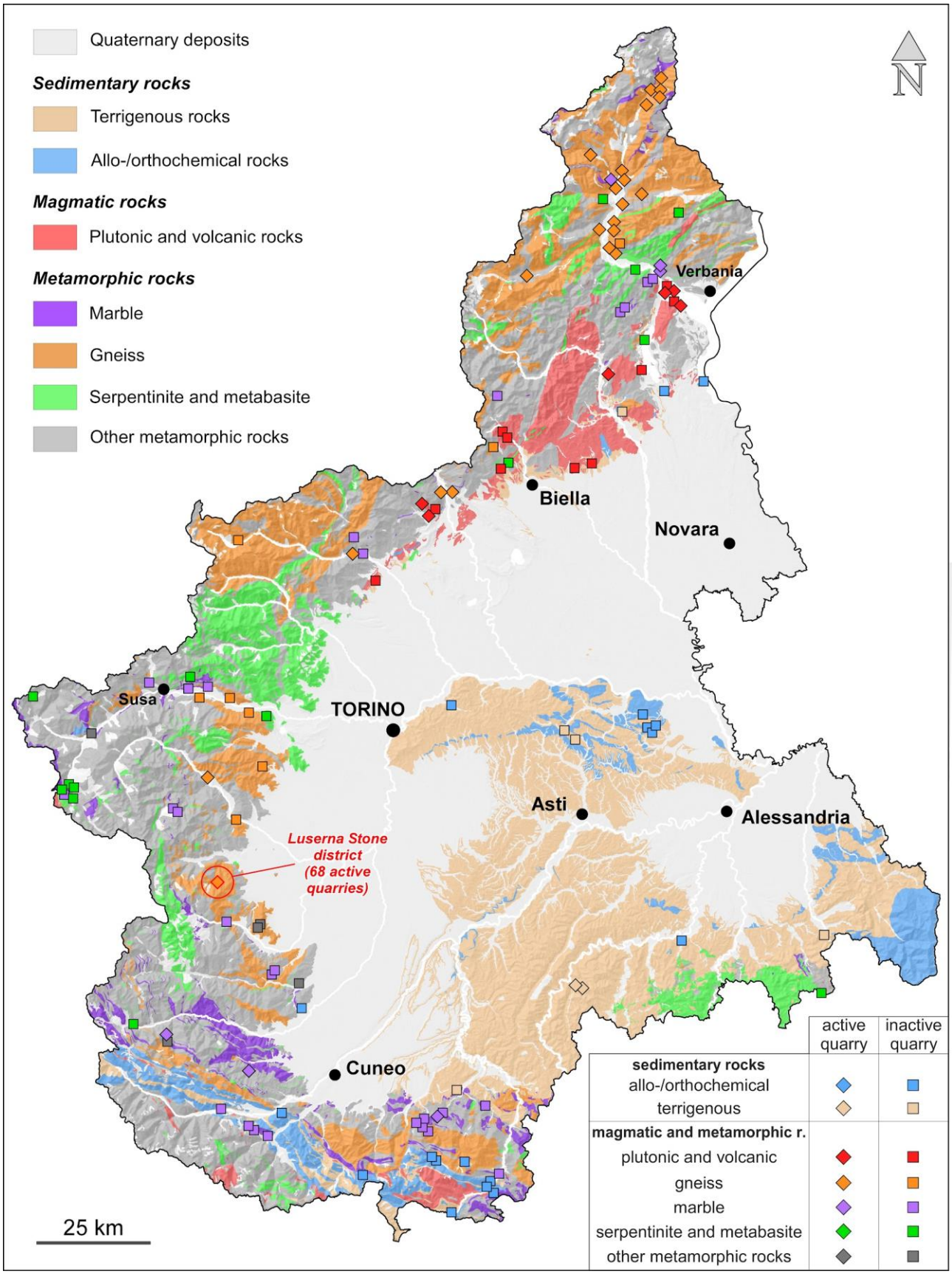

Fig. 2 Simplified lithological map of Piemonte region based on genetic and compositional criteria. The position of the quarries of the Piemonte ornamental stones is also reported. The legend at the bottom right indicates active and inactive quarries with different symbols

For sake of simplicity, the rocks of the geological units cropping out in the Piemonte region have been splitted into the three large groups of sedimentary, magmatic and metamorphic rocks.

Furthermore, the sedimentary rocks have been divided into *terrigenous* and *allo/orthochemical rocks*, according to the Folk classification (1981), which provides for a subdivision conforming to the main sedimentary components; the magmatic rocks have been organised in *plutonic* and *volcanic rocks*, according to the emplacement mechanisms and to the IUGS (International Union of Geological Sciences, Streckeisen et al. 2002), and finally, the metamorphic rocks have been splitted into *marbles* (metamorphic rocks of carbonate composition), *gneisses* (medium-high grade metamorphic rocks of felsic composition), *serpentinite and metabasites* (metamorphic rocks of mafic and ultramafic composition) and *other metamorphic rocks* (e.g. quartzites, calcschists), which are not comprised into the previous categories, according to the Simple Lithology concepts, defined by the IUGS Commission for Geoscience Information (CGI) - Geoscience Terminology Working Group and according to Fettes and Desmons (2007) and Barale et al. (2020).

In conclusion, the Piemonte rocks have been grouped (using strictly lithological criteria) into seven main legend boxes. In this way, petrographically similar rocks are now grouped together even if characterised by very different geological histories, ages and paleogeographic origins.

3. Historical Piemonte ornamental stones and their use

In the following the main ornamental stones used in Piemonte are reported and described separately for each of the above described lithological classes. The classification of the rocks follows the legend of Fig. 2.

3.1 Sedimentary rocks

3.1.1 Terrigenous rocks

The main terrigenous rocks used as ornamental stones are Miocene arenites of the TPB: Pietra di Langa (Langa Stone), Pietra di Vico and Pietra di Montaldero (Vico Stone, Montaldero Stone).

The Pietra di Langa is a turbiditic sandstone of the Cortemilia Formation (late Burdigalian - early Langhian) used in Romanic (e.g. Madonna della Pieve church of Cortemilia – Cuneo) and Renaissance (e.g. Santa Maria Annunziata church in Roccaverano – Asti) ages.

The Pietra di Vico (Vico Stone, Fig. 3a) is a yellow to grey arenite of the San Paolo Formation (Burdigalian) deposited in a shallow water marine environment, characterised by abundant dolomite cement. It was employed in the external cladding of the Sanctuary of Vicoforte (Cuneo) (Fig. 4a). It is a monumental church from the 18th century, among the most important in Piemonte, whose dome, with an elliptical horizontal section, is the largest of this shape in the world.

The Pietra di Montaldero is a bioclastic arenite of Burdigalian age used for the construction of the roman city of Libarna, near Serravalle Scrivia (Alessandria), and in many civil and religious buildings of the Scrivia Valley (Alessandria).

3.1.2 Allochemical and orthochemical rocks

In the antiquity numerous white and coloured limestones were used in Piemonte. Most of the white limestones were quarried from the TPB succession. The most famous quarried material is the Calcare di Gassino (Gassino Limestone, Fig. 3b, Campanino and Ricci 1991), a biocalcirudite rich in red algae and Larger Benthic Foraminifera (LBF) (mainly *Nummulites*) of late Eocene age and cropping out in the Torino Hill. It was used as ornamental stone in the 18th–19th

centuries in Torino in historic buildings such as Palazzo Carignano, Valentino Castle, and finally the Basilica of Superga (Fig. 4b), a religious complex located on the Torino Hill and designed by the baroque architect Filippo Juvarra.

Another historical limestone is the Pietra da Cantoni (Cantoni Stone) (Fig. 3c), a glauconite-rich biocalcarenite of Burdigalian age, quarried in the Monferrato and used since Roman times. It was widely used during the Middle Ages in the Monferrato area (Duomo di Casale, Romanesque country churches) and Torino Hill (Abbazia di Vezzolano).

An important historical allochemical sedimentary material used in the Alessandria province is the Pietra di Visone (Visone Stone). It is a Burdigalian biocalcarenite-biocalcirudite rich in LBF (*Operculina* and *Miogypsina*), deposited in a temperate carbonate ramp, cropping out in the Alto Monferrato. It was used since Roman times, and in the Renaissance period in the Alessandria province (e.g. Acqui Terme Cathedral and Basilica of Santa Croce in Bosco Marengo).

Coloured limestones were exploited from the Triassic-Jurassic succession of the External Briançonnais Domain and largely used as ornamental stones (Persichini, Portoro di Nava, Nero di Ormea) in Torino in the 18th-19th century.

The term "Persichini" (derived from the old Italian “persica”, meaning peach, for their reddish-pink colour) (Fig. 3d) is used for Upper Triassic-Lower Jurassic rocks interpreted as a product of an emersion during the Early Jurassic rifting phases of the Alpine Tethys (De Carlis and Lualdi 2008). They consist of polygenic and polychrome matrix- to clast-supported dolomite breccias, with a dolomitized matrix rich in iron oxides, more or less intensely recrystallised. These breccias, historically known as Persichino di Garessio, Persichino di Corsaglia and Breccia di Casotto (Casotto Breccia) were widely employed for columns in Torino and surroundings (Basilica of Superga, Gran Madre di Dio church in Torino and Sant’Uberto Chapel at Venaria Reale, Torino, Badino et al. 2001).

Among the coloured limestones, the Nero di Ormea (Fig. 3e) is a recrystallised black limestone derived from sediments deposited in a restricted platform environment (Calcari di Rio di Nava, Middle Jurassic). The structure can be uniform (Nero di Ormea) or veined (Portoro di Nava variety). This rock was widely used in the internal decorations of Baroque churches.

The only orthochemical rock used in Piemonte as ornamental stone is the Onice di Busca (Busca Onyx) (Fig. 3f). It was exploited in the past from metre-thick bodies of speleothems (calcite alabaster) filling fissures within the marbles of the Dora-Maira Unit. The Onice di Busca found extensive use in the interior decorations of many Baroque churches in Torino (Marengo et al. 2019). One of the most impressive examples of application of Onice di Busca is in the church of San Filippo Neri, the largest church in Torino, where this material was used to build the columns that delimit the nave, for the balustrades and for the six columns of the high altar.

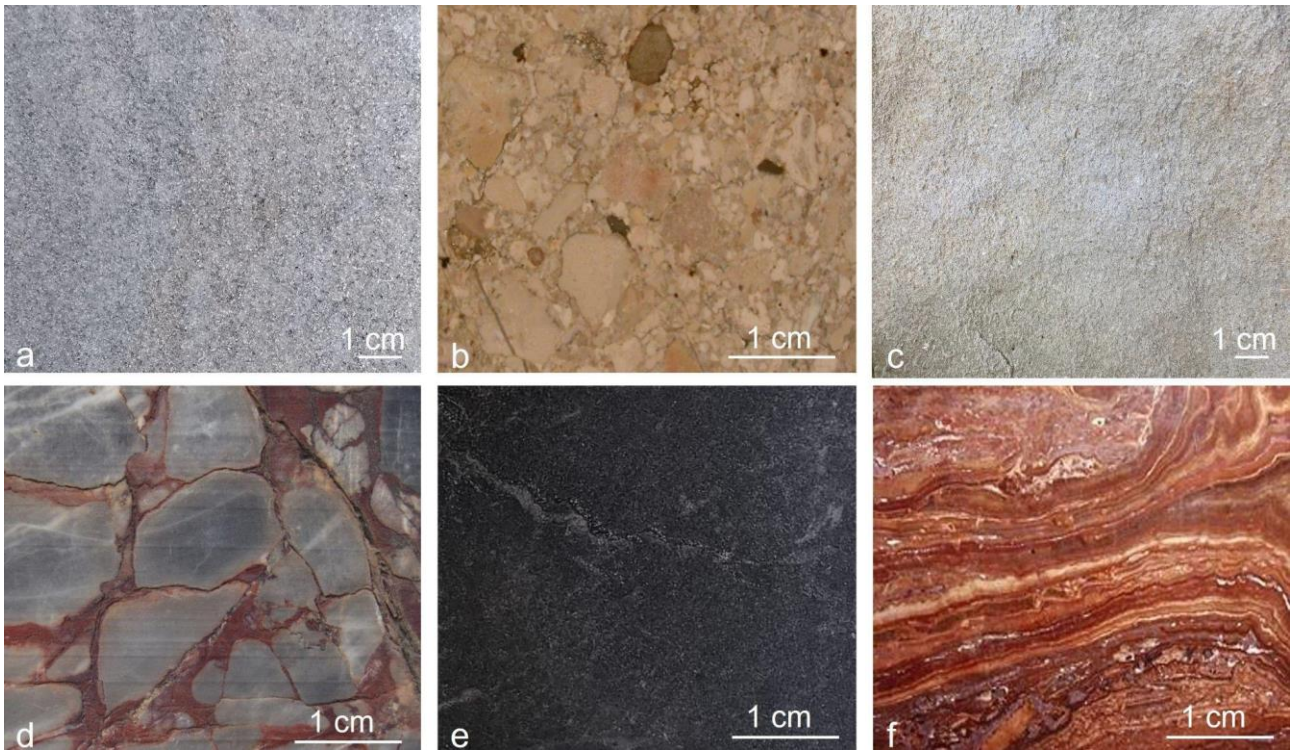

Fig. 3 Macrophotographs of the main sedimentary ornamental stones exploited in the past in Piemonte region: a) Pietra di Vico; b) Calcare di Gassino; c) Pietra da Cantoni; d) Persichini; e) Nero di Ormea; f) Onice di Busca

3.2 Magmatic rocks

3.2.1 Plutonic rocks

The magmatic rocks, although not extensively occurring in Piemonte, show different varieties of ornamental stones.

The Mottarone-Baveno Pluton, which is located between the Toce River and Maggiore Lake, extends at the surface for about 30 km^2. The lower portion of this pluton consists of white granite, while the upper part is formed by pink granite (Caironi et al. 2006). The first traces of granite exploitation, mainly from "pedrere" (areas showing the presence of blocks of granite transported by glaciers) and small open-air quarries, are dated to the 15th century, initially in the Montorfano area and then also in Baveno and Mergozzo quarry sites. From the 16th century the exploitation of granite increased more and more, thanks to excavation by means of "cugnere" (a rock-splitting wedge). From the 19th century the quarrying techniques, thanks to the employment of explosives, became more organised and similar to the present ones; such improvement guaranteed the excavation of the material not only for a local supply, but also for a national one (eg. columns of Via Roma in Torino, and the 82 columns of the Basilica di San Paolo fuori le Mura in Roma). The quarries of this material are historically and culturally the most important in the Verbano – Cusio – Ossola area (VCO) (Dino and Cavallo 2014). In particular, the Granito Rosa di Baveno (Baveno Pink Granite, Fig. 5a) is undoubtedly one of the most widely used ornamental stones in Piemonte. It shows a medium to fine grain size and it is characterised by K-feldspar, quartz, plagioclase and biotite, showing a typical pink colour due to the alteration of K-feldspar crystals. This stone derives from the Permian Magmatic Complex of "Graniti dei Laghi" (Mottarone – Baveno Pluton) of Permian age (Boriani et al. 1992) that intruded, at a shallow depth, the Southalpine Domain basement of the Serie dei Laghi Unit. This valuable rock was quarried and worked since the 16th century, but only in the 19th century the number of quarries increased more and more, representing one of the major economic activities in the area. The most important uses of the Granito Rosa di Baveno in

the city of Torino are represented by the columns of the Mole Antonelliana, the façade of the San Carlo church, and the columns and pilasters of the 19th century façade of Palazzo Carignano. Another commonly employed plutonic rock exploited in the VCO-Sesia Valley quarry district is the Granito Bianco dei Laghi. It is similar to the Granito Rosa di Baveno, from which differs by the overall light grey colour, due to the white colour of the K-feldspar crystals. Depending on the site of origin, different varieties of granite can be recognised: the "Granito di Montorfano" (Fig. 5b), characterised by the presence of xenoliths and "spots" of iron oxides, and the "Granito di Alzo", recognizable by the absence of mafic xenoliths. One of the first uses of this granite can be observed in the old village of Montorfano, located exactly above the current main quarry (well-known as Cavadonna, original name of the quarry). In this village the granite, originally exploited from local "pedrere", was used for every structural element and in particular for the dry masonry of the spectacular Romanesque church of San Giovanni, built between the 11th and 12th centuries (Fig. 4c).

The Alzo-Roccapietra Pluton crops out between the lower Sesia Valley and the Orta Lake. The historic quarry sites, no longer exploited due to problems related to the large and heavy Quaternary cover and landscape restrictions, were placed near Alzo and Boleto villages, on the Orta Lake (Novara), and Roccapietra village, in the lower part of Sesia Valley (Vercelli). The granite extracted was widely used for historic buildings in Torino, in particular in the paving of Via Roma and in the stone balustrade of the Umberto I bridge over the Po River. It was also used in the chapels of the Sacro Monte of Varallo (Unesco World Heritage Site) in the Sesia Valley.

The Sienite della Balma (Balma Syenite, Fig. 5c) is quarried from the Oligocene Valle Cervo Pluton cropping out a few kilometres north of Biella, in the Cervo Valley, covering an area of about 35 km^2. According to Bigioggero et al. (1994), the pluton is compositionally zoned and consists of monzogranitic rocks in the core surrounded by a discontinuous portion of syenitic rocks and, finally, by a wide rim of monzonitic rocks. Currently there are no active quarries, but ten abandoned quarries are located among the villages of Rialmosso, Piedicavallo, Balma, Campiglia Cervo, Rosazza and Oropa (Fiora et al. 2000). The Sienite della Balma shows a typical grey-violet colour, due to the K-feldspar, a medium grain size and a well-developed magmatic flow fabric. There are many historical uses of this stone. In Torino it is possible to recognise its presence in several buildings and infrastructures such as: the monument of Emanuele Filiberto Duke of Aosta in Piazza Castello, the pavement of many blocks of Via Roma, the road pavement of the Vittorio Emanuele I and Umberto I bridges, the steps of San Massimo church. In Ivrea, the Olivetti office building (1960 – 1963) is largely covered by this stone.

The Diorite del Canavese (Canavese Diorite, Fig. 5d) derives from the Oligocene Brosso-Traversella Pluton, which crops out in the Canavese area over about 5 km^2 (Peretti 1938). The rock is exploited along the Chiusella Valley (Torino). Currently there is only one active quarry in Traversella. The Diorite del Canavese shows a granular texture and a colour which varies from light to very dark grey depending on the grain size and on the percentage of mafic minerals, represented by amphibole, biotite, and rare pyroxene. Among the sialic minerals, plagioclase mainly occurs in addition to rare quartz and poikilitic K-feldspar. This rock was widely used in Torino for columns in the Sant' Emanuele block in Via Roma, the paving of ancient passageways for cars and carriages in Piazza San Carlo, and the road paving of the Vittorio Emanuele I and Umberto I bridges.

Another interesting intrusive rock is the commercially so-called Granito Nero di Anzola (Anzola Black Granite, Fig. 5e). This ornamental stone, no longer quarried, encompasses a wide range of basic to ultrabasic rocks (from diorite to gabbro – norite up to websterite) of Permian age (Peressini et al. 2007) intruded in the Ivrea-Verbano Zone. It was the only "black granite" quarried in Italy. The extraction of the rock began between 1906 and 1910, with the opening of two quarries at Anzola d'Ossola (Peretti 1938), just upstream of Ornavasso along the middle Toce Valley, in the VCO-Sesia Valley. The

rock was used in Torino for part of the flooring of Via Roma and for the entrance steps of the Santissima Annunziata church. Pebbles of fluvial origin composed of this rock (diorites and gabbros in particular) were used by Romans for the construction of the amphitheatre (Fig. 4d) in Eporedia (current Ivrea) in the 1st century AD (Storta et al. 2022b).

Among the intrusive magmatic rocks worthy of mention is the Rosso Pantheon (Fig. 5f), a Permian granite belonging to the Canavese Zone. It is an isotropic intrusive magmatic rock with homogeneous medium grain, typified by the intense red colour of orthoclase. The paragenesis is completed by plagioclase, quartz, and biotite partially replaced by chlorite. The Rosso Pantheon is a poorly used ornamental stone: the only quarry of this stone was located near Belmonte (Valperga municipality, Torino), where an attempt was made, at the beginning of the 20th century, to start an important quarrying activity. The Rosso Pantheon was used, between the two World Wars, for monumental buildings in the rationalist style of the period, such as, for example, in the Principi di Piemonte Hotel in Torino (Müller 1990).

Fig. 4 Main examples of employment of Piemonte dimension stones in historic buildings: a) Sanctuary of Vicoforte built in Pietra di Vico; b) Basilica of Superga with several elements in Calcare di Gassino; c) Romanesque church of San Giovanni in Montorfano village built with the Granito di Montorfano; d) Eporedia (ancient Ivrea, Torino province) amphitheatre wall mainly built with Diorite and Gabbro variety of the Granito Nero di Anzola

3.2.2 Volcanic rocks

In the Canavese-Biellese area, several metre-thick dykes of subvolcanic porphyritic rocks are intruded in Permian volcanites of the Southalpine Domain, as Pietra del Rongio (Rongio Stone). The Pietra del Rongio (Fig. 5g) is a filonian

rock with oligoporphyritic structure and microcrystalline groundmass. The phenocrysts consist of idiomorphic plagioclase and brown biotite in thin, usually oriented flakes. The rock was used in Castelletto Cervo (Biella province) for the masonry ashlars of the Cluniac Priory of San Pietro and Paolo (Compagnoni et al. 2015), an imposing monumental structure that belonged to one of the richest and powerful monastic foundations of the subalpine Middle Ages.

Finally, the Andesite del Chiavolino (Chiavolino Andesite) (Fig. 5h) belongs to the Oligocene "Biella volcano-sedimentary Suite". It is a fine-grained, effusive magmatic rock with a porphyritic texture and seriate fabric; among the phenocrysts plagioclase, pyroxene, brown hornblende and biotite are recognised. The groundmass is dark grey-purplish in colour. This rock was used for some external columns of the façade of the Basilica of Vercelli (Fig. 7a).

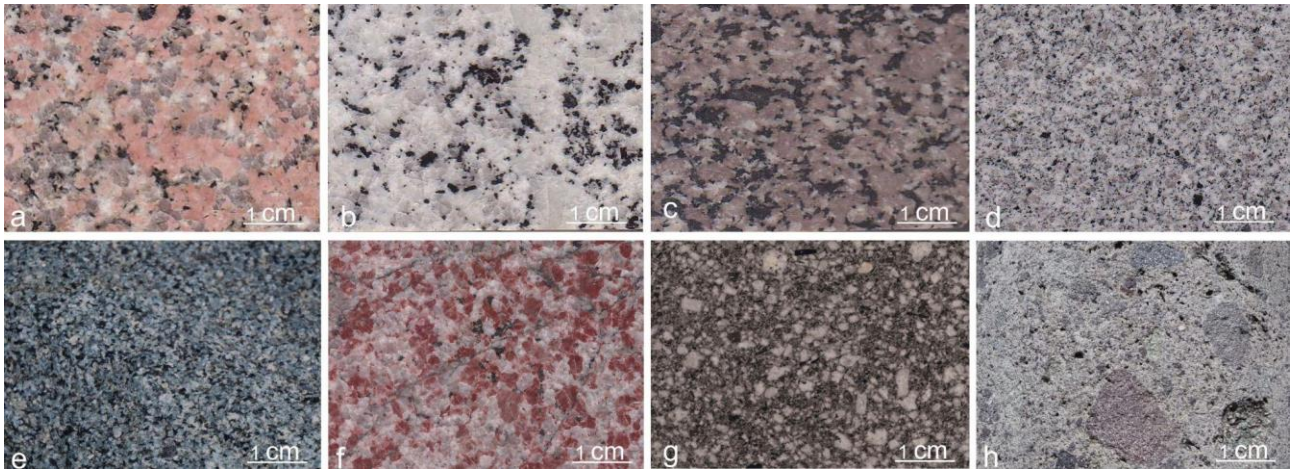

Fig. 5 Macrophotographs of some magmatic ornamental stones of Piemonte: a) Granito Rosa di Baveno; b) Granito di Montorfano; c) Sienite della Balma; d) Diorite del Canavese; e) Granito Nero di Anzola; f) Granito Rosso Pantheon; g) Pietra del Rongio; h) Andesite del Chiavolino

3.3 Metamorphic rocks

3.3.1 Marbles

Some of the oldest and most significant white marbles of Piemonte are the Marmo di Foresto and Marmo di Chianocco (Foresto Marble and Chianocco Marble) (Fig. 6a), whose quarries exploit the metamorphic Mesozoic cover of the Dora-Maira Unit, in Susa Valley. These rocks were used in antiquity for the Arch of Augustus (Fig. 7b) built in Susa (Cottian Alps) in 8 b.c. by King Cozio following the peace with the Romans and dedicated to the Roman emperor (Borghi et al. 2009). The same materials were used in Augusta Taurinorum (Torino) for the statue of Augusto near the Porte Palatine (one of the gates of the Roman city walls) and more recently for church façades, statuary and other architectural and decorative elements, including the Renaissance façade of the Torino Cathedral and the Baroque façade of Palazzo Madama (Borghi et al. 2014; Gambino et al. 2019). Other white marbles extracted from the Dora-Maira Unit are the Paleozoic Marmo di Brossasco (Brossasco Marble) and Marmo di Prali (Prali Marble), used for the columns of the pronaos of the San Filippo Neri church and for the plinths of the entrance portal of the Royal Palace of Torino.

Marbles extracted from the Sesia Lanzo Zone, such as the Marmo di Pont Canavese (Pont Canavese Marble) (Fig. 6b), were used from Roman Age, for example in the precious funerary Stele of the Gromaticus L.A. Faustus, exposed at the Garda Museum of Ivrea (Fig. 7c) (Storta et al. 2022a). It consists of a particular white marble table engraved in the 1st century A.D. It is a unique case of reproduction of the groma, a tool used for the operations of division and measurement

of agricultural land for cadastral purposes. The groma is depicted only on this slab and on a Pompeian one from the 1st century A.D., in which it is however assembled and reproduced with less attention to details (Panerai 1984).

An important historical marble is the Marmo di Candoglia (Candoglia Marble, Ivrea-Verbano Zone) (Fig. 6c), quarried for the exclusive use of the Veneranda Fabbrica del Duomo di Milano since 1387, the year in which Duke Gian Galeazzo Visconti obtained the authorization to exploit this stone. From that time this rock has been - and still is - employed uniquely for the construction and the maintenance of the Duomo di Milano (Milan Cathedral). The presence of rivers (Toce and Ticino) and the construction of canals (Navigli) guaranteed the direct and easy transport from the quarry area located in Ossola Valley (VCO) to Milano. Thus, the Marmo di Candoglia was preferred to other more famous Italian marbles (e.g., Carrara marble) even if its textural features (coarse grain-size) were not fully suitable for statuary applications (Dino et al. 2019).

Another Piemonte marble widely used in the past is the Marmo di Frabosa (Frabosa Marble, Internal Briançonnais Domain), mainly used for statuary, given its easy workability due to its fine and homogeneous grain distribution. The Marmo di Frabosa was used in the external and internal decorations of the façades of some Baroque churches in Torino, such as the capitals in white variety and internal slabs in the “Verzino” (green) variety (Fig. 6d) of the Gran Madre di Dio church, the decorations of San Carlo and Santa Cristina churches, statues and pinnacles in the Palazzo Carignano and the pediment of San Filippo Neri church (Gambino et al. 2019). The black and "bigio" (grey) varieties were employed for the Chapel of the Holy Shroud (dome cladding). Another black marble is the Nero Nuvolato di Miroglio, employed in Torino for the atrium of the Galileo Ferraris Institute (former site of the Italian Standard Time) and for the Gran Madre di Dio church (internal decoration of the Ossario dei Caduti). Among the coloured marbles, the Bigio di Moncervetto (Fig. 6e) consists of a veined marble belonging to the Middle Triassic succession of the Internal Briançonnais Domain (Badino et al. 2001). This marble shows a light grey colour and a fine grain, and is crosscut by a network of large, coarsely-crystalline calcite veins. This is the only coloured marble still extracted in Piemonte from a quarry located at 900 metres a.s.l. on the left side of the Corsaglia Valley near Monastero di Vasco (Cuneo) (Badino et al. 2001). The origin of the quarries dates from the 14th century, but it is only in the 16th and 17th centuries that a more intensive exploitation took place. The area was of particular interest for the Savoy kingdom (which in the past included the Piemonte region) quarrying activity, as many ornamental stones of different colour were exploited and used in lots of churches and palaces throughout the region such as the Sanctuary of Vicoforte and the Basilica of Superga (Badino et al. 2001). Finally, it is worth mentioning the Bardiglio di Valdieri (Fig 6f), a grey listed marble deriving from Cretaceous sedimentary successions of the Palaeo-European Continental Margin metamorphosed during the Oligocene by hydrothermal processes, and widely used from Roman times to the 18th century. It represents the most used listed marble employed in Piemonte, especially in the Baroque age.

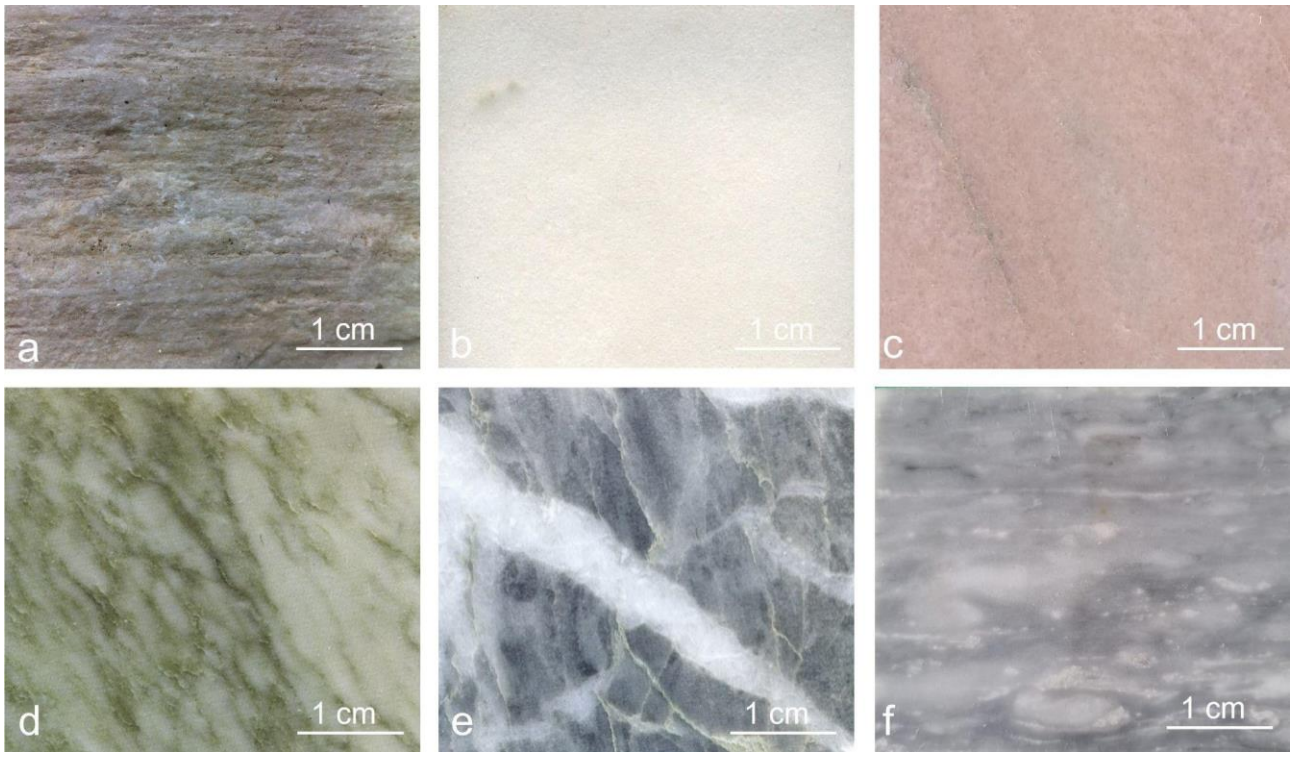

Fig. 6 Macrophotographs of marbles quarried in the past as ornamental stones: a) Marmo di Foresto; b) Marmo di Pont Canavese; c) Marmo di Candoglia; d) Marmo verzino di Frabosa; e) Marmo Bigio di Moncervetto; f) Marmo Bardiglio di Valdieri

3.3.2 Gneisses

This category of metamorphic rocks is mainly represented by gneisses coming from Western Alps valleys. Among these, the rock most widely employed is certainly the Serizzo (Fig. 8a). The Serizzo, the most important dimension stone from VCO-Sesia Valley district (Sandrone et al. 2004), consists of a large variety of orthogneisses characterised by "augen texture" (Sandrone et al. 2004). These rocks derive from Permian granites (270-280 Ma) and were pervasively equilibrated during the Alpine orogenic event under amphibolite facies conditions (Cavallo et al. 2004b). Three main varieties can be recognised: Antigorio, characterised by a darker colour, Formazza and Sempione. There is also a fourth variety, the Serizzo Monte Rosa, which, however, belongs to a different geological unit (Monte Rosa Unit, Upper Penninic Domain). There are several active quarries, mostly located in the Antigorio and Formazza valleys. The Serizzo has been widely used over the centuries for local and non-local architectural uses: among the first the church of Santa Maria Assunta in Montecrestese (VCO) built between the 16th and 17th centuries. Not far from the church, on a small hill, stands the bell tower, which with its 67.5 metres high represents the tallest bell tower in the Ossola area (Fig. 7d). Its great exploitation dates back to 20th century: it was largely used in northern Italy, as an external covering for buildings, columns, plinths and flooring. In Milano it was used for the paving of XXV Aprile square, while in Torino the Serizzo Antigorio and the Serizzo Formazza were used for the flooring of the Porta Nuova railway station and in the construction of the 180 columns of the Via Roma arcades between Piazza San Carlo and Piazza Carlo Felice.

Another important metamorphic ornamental stone of the VCO-Sesia Valley is the Beola (Fig. 8b), which belongs to the Lower Penninc Domain and whose main varieties are "Grigia" and "Favalle". The term "Beola" refers to numerous varieties of orthogneiss with relatively similar mineralogical composition and characteristics coming from different lithological units in the area between Vogogna and Montecrestese. There are currently 7 active quarries of this material.

The term "Beola" or "Bevola" originally derives from the name of the city where the largest number of quarries were present in the 15th century (Bevola, today Beura, Cavallo et al. 2004a). Most probably the trade in this stone material began around the end of the 13th century, coinciding with the new possibility of navigating the Grande Naviglio channel to Milano. On the other hand, it is also probable that the Romans had already exported the stone from the city of Beura, considering that the ancient Roman road crossed that location, as evidenced by an epigraph from 196 AD sculpted near Vogogna (Cavallo et al. 2004a). In addition to contemporary building cladding, flooring and street furniture, interesting historical examples of applications with Beola are the 15th century village and the castle of Vogogna (VCO province).

A further important metamorphic stone, being one of the most important materials used in the city of Torino, is the Pietra di Luserna (Luserna Stone, Fig. 8c). It is an orthogneiss belonging to the Dora-Maira Unit, derived from Permian plutonic rocks. The Pietra di Luserna shows a light grey colour and a good fissility, which makes it easy to split the rock along the schistosity planes. The rock crops out over an area of about 50 km^2 in the Cottian Alps, at the border between Torino and Cuneo provinces. The Pietra di Luserna quarries (49 open quarries in 2023; Regione Piemonte 2023), located at altitudes between 900 and 1500 m a.s.l., are in Bagnolo Piemonte, Rorà and Luserna San Giovanni municipalities. The Pietra di Luserna was used for the dome of the Mole Antonelliana, the symbol of Torino, for the paving of many squares and streets in the historic centre of Torino, for the façade of the Automobile Museum, for the pavements of the Vittorio Emanuele I and Umberto I bridges, which cross the Po River.

A variety of slightly darker orthogneiss is the Pietra di Malanaggio (Malanaggio Stone, Fig. 8d), an amphibolic - biotitic orthogneiss intruded in the crystalline basement of the Dora-Maira Unit. The quarrying activities started in the early 19th century with the opening of five quarries in the territory of Porte and Perosa Argentina (Chisone Valley) and ended after World War II due to the low request of stone materials and the decrement of manpower. There is only one open quarry in the village of Brandoneugna (Chisone Valley, Torino), where the so-called "Pietra di Perosa" (Perosa Stone) is exploited.

In the past, the lower Susa Valley (Torino) was characterised by the presence of numerous quarries for the exploitation of gneisses of the Dora-Maira Unit, namely the Gneiss di Borgone, Gneiss di Vaie, Gneiss di Villar Focchiardo and Pietra di San Basilio (Borgone, Vaie and Villar Focchiardo Gneiss, San Basilio Stone) (Barisone et al. 1992). The discovery of prehistoric objects near Vaie quarry suggests that these materials were employed during the Bronze Age; they were certainly used during the Roman age (Fiora and Gambelli 2003). In particular, the Pietra di San Basilio (Fig. 8e), corresponding to the historic Gneiss di Villar Focchiardo, consists of a tourmaline-rich leucocratic orthogneiss, and is light grey in colour. It is characterised by a granitic composition and shows a foliation defined by mica lamellae and by the orientation of tourmaline blasts (Borghi et al. 2016). In the Exilles Fortress, located in the middle Susa Valley, all these stones were used. In particular, the walls consist of blocks of strongly schistose and easily splittable rock types. In particular, the Gneiss di Villar Focchiardo was employed for embrasures that overlook the western side, whereas the Gneiss di Borgone and Gneiss di Vaie were used in the masonry and for the fountain of the main parade ground.

Other important gneiss varieties are the jadeite- and phengite-bearing orthogneisses that have been exploited in the Sesia Lanzo Zone as granites from the economic-commercial point of view (Verde Argento and Verde Selene). The Verde Argento (Fig. 8f) is characterised by a regional metamorphism of high pressure and low temperature. The first evidence of the use of Verde Argento dates back to the 18th century: the rock was used, for example, as an external covering and in the plinths in the nearby church of the Madonna del Rosario and of the Santi Maurizio and Germano in Borgofranco d'Ivrea (Torino). At the end of the 19th century, the rock was used extensively in the construction of the railway stations

connecting Chivasso and Aosta, and in particular in the structure of the railway underpasses in the line between Ivrea and Pont-Saint-Martin (Aosta). Other historical uses are also attested in the Court Building of Ivrea and in other cities for buildings, churches, cemeteries, sidewalks and vineyard supports in the municipalities of Borgofranco, Tavagnasco and Settimo Vittone. Starting from 1975 the quarry became the property of the Vuillermin Company, which has marketed the Verde Argento all over the world; reference examples are the façade of the Presidential Palace in Malé, capital of the Republic of Maldives, and the internal covering of the Singapore subway. Even in Italy, in the area between Piemonte and Aosta Valley, the Verde Argento has been used for the construction of public and private buildings, as well as for restoration and adornment works of the Agliè Castle and the Bard Fortress (Vuillermin 2023).

Finally, the Verde Oropa must be mentioned. This is a heterogeneous gneiss of the Sesia Lanzo Zone in which leucocratic domains alternate with melanocratic ones: the latter are green in colour and partially preserve eclogitic paragenesis. From a macroscopic point of view, it is possible to recognise quartz, mica, pyroxene, garnet and epidote. This stone was quarried close to the Oropa Sanctuary (Biella), where it was widely used for the cloister columns and for the external cladding of the walls.

3.3.3 Serpentinite and metabasites

Quarries of serpentinite and metabasites are particularly concentrated in the upper Susa Valley sector, where the rocks of the Liguria-Piemonte Oceanic Units occur. These rocks, although easy to work, have been used less than marble and limestone, also because the outcrops are not extensive and continuous and therefore the rocks are difficult to extract. The Verde Susa and the Verde Alpi Cesana (Fig. 8g) represent the most used varieties in the 19th and 20th centuries, for example in the urban passages of Torino (Fiora and Di Pierro 1998). Macroscopically, the rock is typified by the pervasive network of carbonate veins. While in the lower and middle Susa Valley similar materials were already exploited in ancient times from erratic boulders, in the upper Susa Valley the quarries were opened at the end of the 19th century and the exploitation continued until the mid-1980's.

Serpentinite and metabasites (Prasinite della Val di Susa) were also used in the mediaeval time, for example in the Sacra di San Michele (UNESCO World Heritage Site candidate) for all the external walls and arches (Borghi et al. 2016). The Sacra di San Michele (Fig. 7e), standing on top of Monte Pirchiriano at 962 m a.s.l., near Sant'Ambrogio village, on the southern side of the Susa Valley, was one of the most important fortified monasteries in southern Europe. Because of its strategic position it was an important stronghold of the Via Francigena, one of the most ancient communication routes in Europe. Another important use of metabasites is represented by the Fenestrelle Fortress, built in the 18th century across the valley bottom of the Chisone Valley, to defend the Savoy kingdom borders (Fiora et al. 2006).

Fig. 7 a) Cathedral of Vercelli, in which Andesite del Chiavolino was used for columns; b) Arc of Augustus at Susa (Roman Age, 9 BC) built with the Foresto and Chianocco marbles; c) Funerary Stele of the Gromaticus carved using the Marmo di Pont Canavese and preserved at the Garda Museum of Ivrea (Torino); d) Santa Maria Assunta bell tower built in Serizzo at Montecrestese, Ossola Valley; e) Façade of the Sacra di San Michele made of serpentinite and metabasites

3.3.4 Other metamorphic rocks

The Quarzite di Barge (Barge Quartzite), called Bargiolina (Fig. 8h), is a micaceous fine-grained quartzite showing a tabular and homogeneous appearance. The quarries are located on the western side of the Monte Bracco (lower Po Valley). The Bargiolina – known and used since the prehistoric age as substituting material for chert-replacing material, and celebrated by Leonardo da Vinci (Cavallo and Dino 2019) – was intensely exploited from the early 20th century. It is a valuable dimension stone, used as internal and external stone facing, because of its excellent technical properties (Peretti 1938). For example, it was used for the internal floors of the Regional Museum of Natural Sciences in Torino and in

several churches in Piemonte (e.g. Basilica di Superga and San Filippo Neri church). The quartzite crops out at 1100 to 1200 m a.s.l.. Geologically it represents the product of the Alpine metamorphism of Permo-Triassic quartz-arenites deposited above the Dora-Maira Unit during the post-Variscan marine transgression (Vialon 1966). There are different chromatic varieties of Bargiolina: golden yellow, pale yellow, olive grey, grey and white (Marmorina variety). The main technical characteristic of the Bargiolina is the regular schistosity, due to thin phengite mica layers along which the rocks can be splitted into very thin slabs (1-2 cm thick).

Finally, the Pietra di Piasco (Piasco Stone) is here mentioned; it is represented by a grey schistose metamorphic rock, made of white mica, quartz and feldspars, intensely altered, coming from the calcschists of the Liguria-Piemonte Oceanic Units. It was used throughout the 19th century in several Piemonte monuments, such as some columns and portals in Piazza Vittorio Veneto in Torino, in the Cathedral of Fossano (Cuneo), and for several local uses in Varaita Valley (Cuneo).

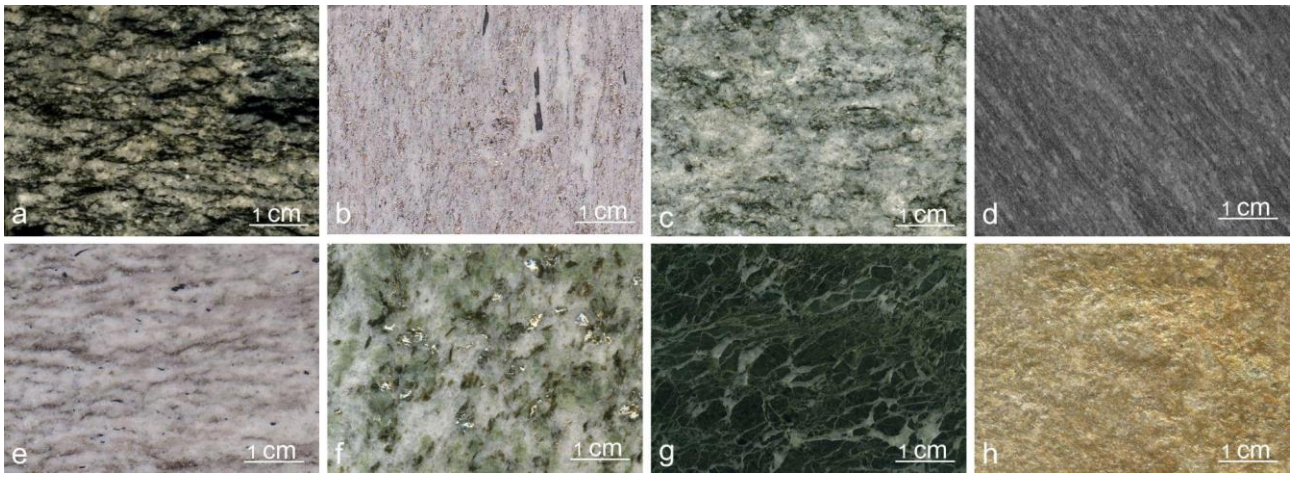

Fig. 8 Example of the most important metamorphic ornamental stones: a) Serizzo Antigorio; b) Beola; c) Pietra di Luserna; d) Pietra di Malanaggio; e) Pietra di San Basilio; f) Verde Argento; g) Verde Alpi Cesana; h) Bargiolina

4. The database

The extensive amount of collected data on the historical and cultural heritage regarding the stone materials of Piemonte has been stored in a DB supporting the Geological Map graphic representation (Fig. 2). A Data Model was built for the implementation of the DB in order to retrieve the basic geologic information of the GeoPiemonte Map DB (Piana et al. 2017a, b) and to fit it for this thematic purpose. The Data Model was thought to allow linking of the GeoPiemonte Map DB with the new structure of the Ornamental Stone DB. The original Property Classes of the GeoPiemonte Map DB were thus reorganised in order to represent the new instances of the more simple Legend of the Ornamental Stone DB, into the new DB structure. This was designed to avoid loss of crucial geologic information, as well as to allow describing of new properties such as, for instance, the historical-architectural uses of the stones.

The resulting Ornamental Stone DB, extensively described in Barale et al. (2020) consists of 25 fields (columns) that describe several geological properties of the stones, as well as their present and historical usages. As the fields of the DB of the WebGIS service are labelled in Italian language, their translations are reported in the following:

SIGLA: identity code; ID_COR: geological unit identification code; COD: ornamental stone identification code; LITHO_CODE: lithology identification code; NOME_COMMERCIALE: commercial name; VARIETA_ALTRI_NOMI: varieties or other name of the ornamental stone; X and Y: geographic coordinates of the

quarry; LOCALITA_ESTRAZIONE: locality of extraction; DISTRETTO_ESTRATTIVO: quarry district; ATTIVA: present state of activity of the quarry (yes/no); NOME_PETROGRAFICO: petrographic name of the rock; LITHO_UNIT: geological unit to which the rock belongs; DOMINIO: geological domain to which the rock belongs; GEOL_UNIT_1, 2, 3: higher-ranking geological units to which the rock belongs (as subdivided in the GeoPiemonte Map by Piana et al. 2017a, b); GRUPPO_ROCCIA: rock type; DESCRIZIONE: synthetic lithological description; DUREZZA: hardness of the rock; UTILIZZI_PRINCIPALI: main uses in the architectural field; PERIODO_IMPIEGO: historical age when the stone was mainly used; BIBLIOGRAFIA 1, 2: main references; NOTE: notes (curiosity, website links etc.) (Fig. 9).

5. The Interactive Geolithological Map of ornamental Stones of Piemonte (WebGIS service)

The Geolithological Map of the ornamental Stones of Piemonte (Barale et al. 2020) is now available as a WebGIS service consisting of an interactive map with queryable DB: https://webgis.arpa.piemonte.it/agportal/apps/webappviewer/index.html?id=6ea1e38603d6469298333c2efbc76c72.

The map shows the locations of the main quarries in the region, selected on the basis of their cultural, historical and economic significance. The location of the quarries is indicated with a symbol (crossed hammers), distinguishing the active (red) and inactive (black) quarries. The symbol has been positioned next to the quarry areas (for active ones) and on the basis of excavation evidence or historical information (for inactive ones). For some lithotypes, occurring in extensive extraction basins with multiple quarries, only the largest or most significant quarries have been reported. Clicking on the symbol of a quarry (e.g. in Fig. 9 the Pietra di Perosa quarry), a pop-up window opens showing a series of geological and historical-archaeological detailed information about the extracted ornamental stone.

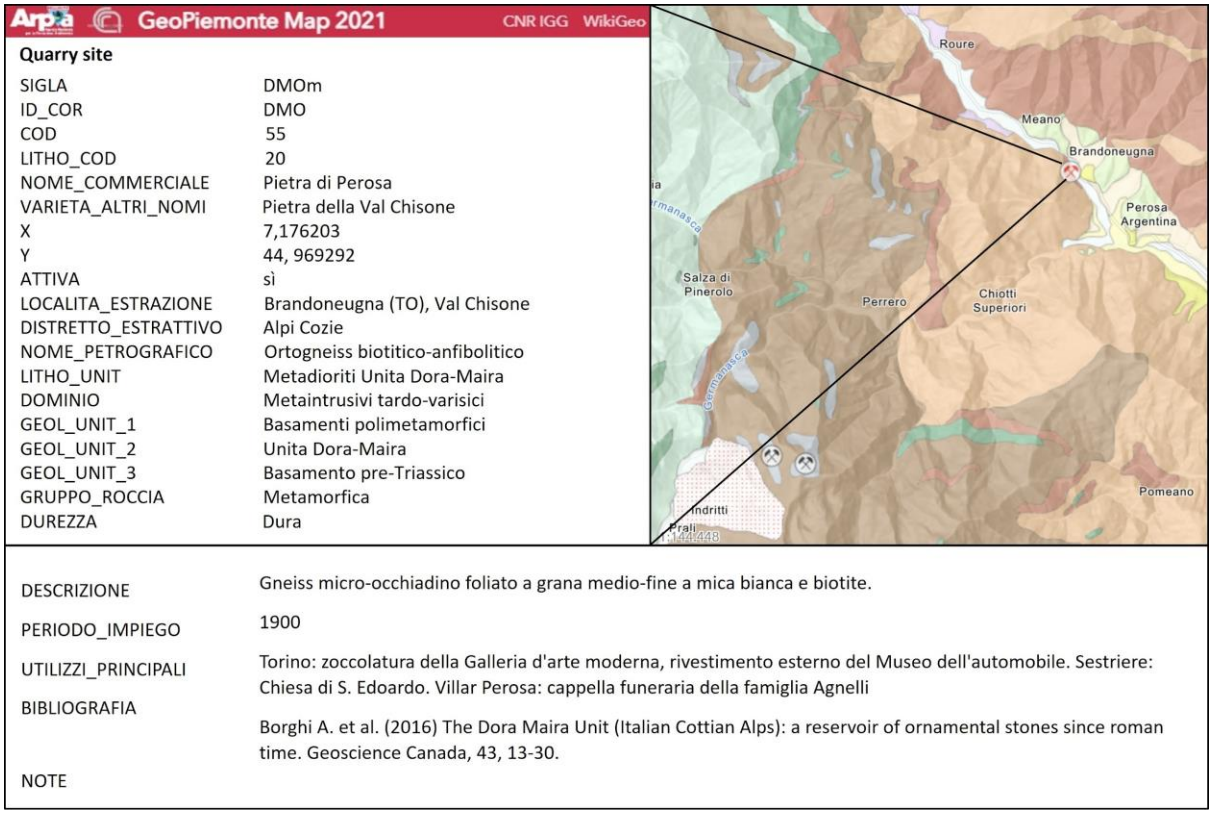

Fig. 9 Example of pop-up window and location of the quarry on the GeoPiemonte Map for the Pietra di Perosa

An excerpt from the DB containing the main information on the various ornamental rocks is shown in Table 1 in Supplementary Materials.

On the basis of the list of lithologic varieties and according to their genesis (genetic classes, Fig. 10a) the most abundant ornamental stones are metamorphic ones (65%), followed by sedimentary rocks equal to 20% and finally magmatic ones corresponding to only 15 %.

In particular, regarding the metamorphic rocks (Fig. 10b), marbles (42%), mainly present in the VCO area, and in the southern sector of Cuneo province, are followed by gneisses (39%), which are mainly distributed in the northern sector of the VCO (Serizzo and Beola), Sesia Valleys and in the Cottian Alps (Pietra di Luserna); follow the serpentinite and the metabasites (15%) extracted above all in the Susa Valley and, in part, in the Ossola Valley; the other metamorphic rocks, not included in the previous categories, are only the 4%.

Furthermore, it should be noted that igneous rocks (Fig. 10c), mainly cropping out in the VCO and Biella provinces, include both plutonic rocks (80%), present in 16 varieties, and volcanic (20%) ones, quarried in 3 different varieties.

Among the sedimentary rocks (Fig.10d), 67% are allochemical, concentrated in the Cuneo and Asti-Alessandria provinces, 28% are terrigenous and finally only 5% are orthochemical rocks.

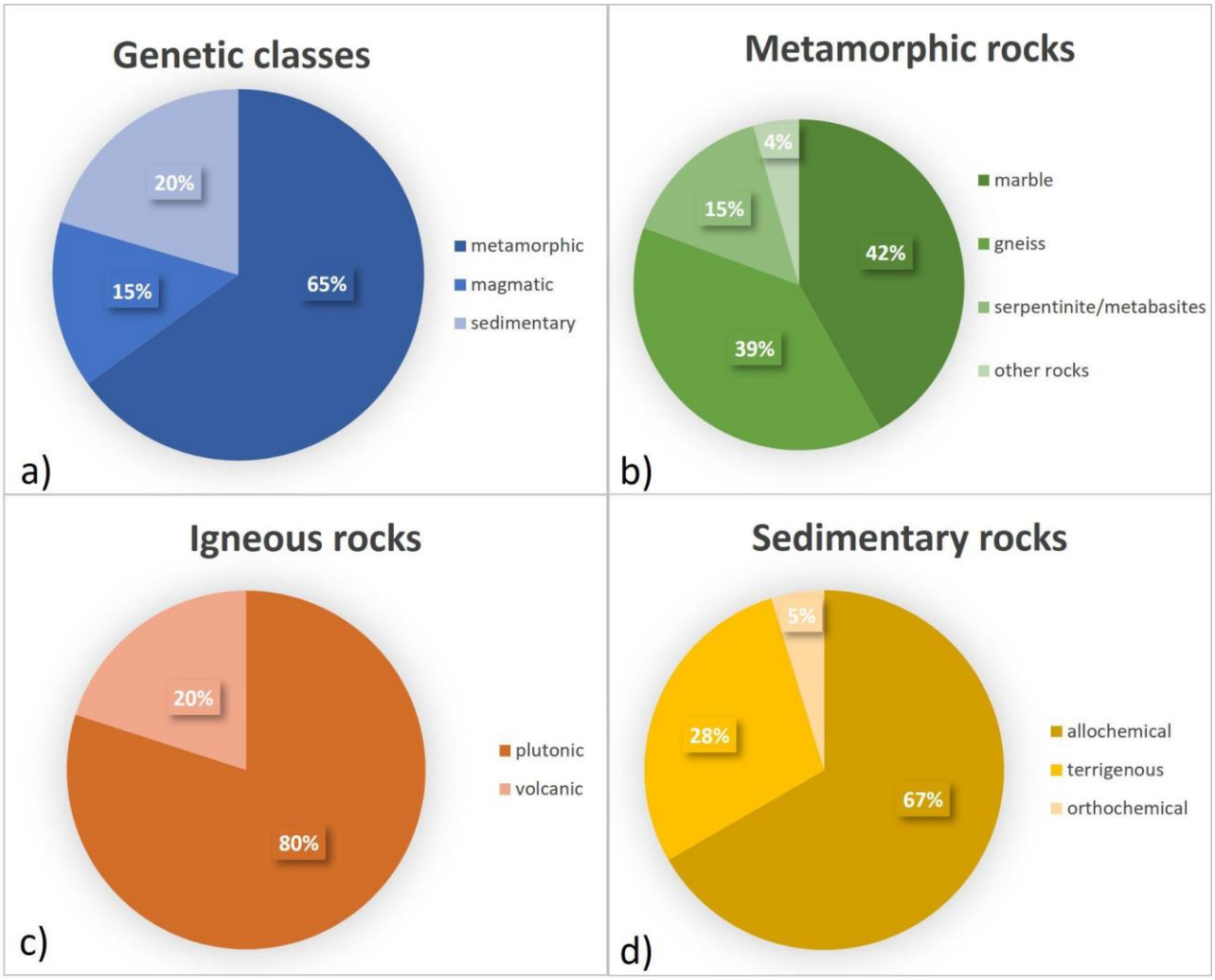

Fig. 10 Diagrams showing the different subdivisions for the ornamental stones of Piemonte region according to genetic

classes (a); the percentage of the rocks, according to their origin, is shown respectively in b) metamorphic, c) igneous and d) sedimentary

6. Conclusions

The present work reports the results of a research aimed at cataloguing and organising historical ornamental stones of Piemonte region, their lithological descriptions and main uses in the cultural field.

In particular, a census was carried out, followed by the geological characterisation and historical uses for each ornamental stone. In this way, through the DB and the related WebGIS, for the first time, ornamental stones are represented in an organic document based on geological cartography.

This leads to assert that the Piemonte region has been characterised through the centuries by the use of stone in constructions such as religious buildings, of military defence and of the main institutional buildings. However, the stone was also used in the civil sector, particularly in rural buildings in the Alps, as well as, in recent years, for urban furnishings, and in infrastructural works such as bridges, arcades and paving roads.

The characterisation of the stones employed is a fundamental step for the enhancement of such valuable material and is addressed not only to geologists, but also to public administrations, industries, experts in social sciences and history, experts in cultural heritage, citizens in general, etc. To enhance the heritage stone of the region, the Interactive Geolithological Map of the ornamental Stones, through a WebGIS service with an associated DB, was built. In this way, the DB could be a part of a wider tool for natural stones around the world. This tool allows the dissemination of historical and geological information to a wider audience, through appropriate scientific dissemination paths. The Interactive Geolithological Map of the ornamental Stones of Piemonte is a thematic map, developed from the GeoPiemonte Map (Piana et al. 2017a), useful for scientific and educational dissemination purposes, to be used by public administrations and geo-sciences professional communities. For each quarry site in the Map, a synthetic description in a WebGIS pop-up window is provided.

The interactivity of the map allows a continuous implementation and update of the data. The discovery of new lithological varieties and of unknown historical quarries can be easily reported in the map.

In conclusion, the aim of the Geolithological Map of the ornamental Stones of Piemonte, now available as a WebGIS service, is to raise public awareness about the fundamental role that Earth sciences play in the enhancement of cultural heritage, by the application of the scientific method to the comprehension and conservation of historic buildings and monuments.

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Captions

Fig. 1 Scheme showing the present distribution of the palaeogeographic domains of the Piemonte region (from Piana et al. 2017a, b)

Fig. 2 Simplified lithological map of Piemonte region based on genetic and compositional criteria. The position of the quarries of the Piemonte ornamental stones is also reported. The legend at the bottom right indicates active and inactive quarries with different symbols

Fig. 3 Macrophotographs of the main sedimentary ornamental stones exploited in the past in Piemonte region: a) Pietra di Vico; b) Calcare di Gassino; c) Pietra da Cantoni; d) Persichini; e) Nero di Ormea; f) Onice di Busca

Fig. 4 Main examples of employment of Piemonte dimension stones in historic buildings: a) Sanctuary of Vicoforte built in Pietra di Vico; b) Basilica of Superga with several elements in Calcare di Gassino; c) Romanesque church of San Giovanni in Montorfano village built with the Granito di Montorfano; d) Eporedia (ancient Ivrea, Torino province) amphitheatre wall mainly built with Diorite and Gabbro variety of the Granito Nero di Anzola

Fig. 5 Macrophotographs of some magmatic ornamental stones of Piemonte: a) Granito Rosa di Baveno; b) Granito di Montorfano; c) Sienite della Balma; d) Diorite del Canavese; e) Granito Nero di Anzola; f) Granito Rosso Pantheon; g) Pietra del Rongio; h) Andesite del Chiavolino

Fig. 6 Macrophotographs of marbles quarried in the past as ornamental stones: a) Marmo di Foresto; b) Marmo di Pont Canavese; c) Marmo di Candoglia; d) Marmo verzino di Frabosa; e) Marmo Bigio di Moncervetto; f) Marmo Bardiglio di Valdieri

Fig. 7 a) Cathedral of Vercelli, in which Andesite del Chiavolino was used for columns; b) Arc of Augustus at Susa (Roman Age, 9 BC) built with the Foresto and Chianocco marbles; c) Funerary Stele of the Gromaticus carved using the Marmo di Pont Canavese and preserved at the Garda Museum of Ivrea (Torino); d) Santa Maria Assunta bell tower built in Serizzo at Montecrestese, Ossola Valley; e) Façade of the Sacra di San Michele made of serpentinite and metabasites

Fig. 8 Example of the most important metamorphic ornamental stones: a) Serizzo Antigorio; b) Beola; c) Pietra di Luserna; d) Pietra di Malanaggio; e) Pietra di San Basilio; f) Verde Argento; g) Verde Alpi Cesana; h) Bargiolina

Fig. 9 Example of pop-up window and location of the quarry on the GeoPiemonte Map for the Pietra di Perosa

Fig. 10 Diagrams showing the different subdivisions for the ornamental stones of Piemonte region according to genetic classes (a); the percentage of the rocks, according to their origin, is shown respectively in b) metamorphic, c) igneous and d) sedimentary

Title: The Database~~DataBase~~ of the ornamental stones of Piemonte (NW Italy) hosted on a WebGIS service

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Abstract:

In Piemonte (north-western Italy), an intense extraction activity of ornamental stones widely used for historical buildings, developed throughout centuries. This is due to the wide geodiversity of the region, characterised by mostly metamorphic and magmatic rocks in the Western Alps and by terrigenous and carbonate sedimentary rocks in the Alps-Apennines syn-orogenic basins.

The work presents the description and classification of the main Piemonte ornamental stones, referring to a simplified lithological Map Legend. To enhance the remarkable historical and contemporary stone heritage of the ~~Piemonte~~ region ~~(NW Italy)~~ a database (DB) was developed addressing a proper cataloguing of the ornamental stones~~stone materials~~ and related quarries. The ~~This allowed the attribution of the~~ classified instances have been referred to the geologic units of a ~~simplified,~~ regional-scale, interactive geological map, ~~(the "Interactive Geolithological Map of the ornamental Stones of Piemonte"),~~ in which each ornamental stone~~stones~~ was attributed~~allocated~~ to few geo-lithological~~thematic~~ classes.

~~-~~The map was ~~then~~ developed as a WebGIS~~Web GIS~~ service hosted on a geoportal (https://webgis.arpa.piemonte.it/agportal/apps/webappviewer/index.html?id=6ea1e38603d6469298333c2efbc76c72) that allows interactive querying and download of the DB~~database~~ information, regarding the main rock types and the corresponding quarries, as well as their historical-architectural uses, to underline their value as witness of cultural heritage. The WebGIS service is progressively fed~~constantly feeded~~ by new data, in order to become~~be recognised as~~ a relevant source of information for those working in the field of cultural heritage~~Cultural Heritage~~ and geo-environmental sciences.

~~The present paper describes how the database was built and how the interactive geological map was drawn up, as well as the main ornamental stones of Piemonte, divided according to their geological origin and their use in the historical architectural field.~~

Keywords: Ornamental stones, Geological map, Database, Quarries, Piemonte, WebGIS service

1. Introduction

Stone has always represented one of the main sources of material in the construction industry and, in particular, an important cultural element as it is used as raw material in the field of sculpture and architecture, which is now part of the cultural heritage of humanity (Borghi et al. 2014; Brocx and Semeniuk 2019). Therefore, the knowledge of stone resources, their minero-petrographic characteristics and their use from Antiquity to the Present can provide a broad historical and cultural panorama of these materials, underlining the importance of a very relevant economic activity in the history and traditions of the different cultures (Cooper 2015). Indeed, the scientific knowledge (location of the quarries, geological features, petrographic composition, historic use and heritage utilisation and related heritage issues of stones) of some important ornamental stones designed as "Global Heritage Stone Resource" (GHSR), would generally lead to a greater awareness of the importance of stone as a common good and therefore to their recognition by national and international authorities (Cooper et al. 2013). From the time of the ancient Greeks and Romans, natural stones have been used in construction, architecture and all kinds of arts due to their durability, but also to their beauty (Pensabene 1998; Lazzarini 2004). Over time, many books have been published relating to the ornamental stones from different countries such as Great Britain (Walkden 2017), Baltic states (Selonen and Suominen 2003), Germany (Ehling et al. 2021) and Egypt (Klemm and Klemm 2012). Around the beginning of the 20th century (Pereira and Marker 2016) many cities such as Helsinki and St Petersburg used ornamental stones (Bulak 2016), but also Paris and other European cities (DeWever et al. 2016). Natural stones have also been widely used for statues preserved in various museums (Pereira and Perez-Castro 2019).

Even the~~Every~~ Italian regions are typified~~region is represented~~ by buildings and monuments often made of natural stone. In particular, in Piemonte (NW~~north western~~ Italy), stone has always been the most widely used building material, characterising the architectural identity not only of cities, but also of rural buildings widespread in the Alpine valleys. In Piemonte, stone has always been used in historic and contemporary buildings, monuments and street furniture, showing the close link that exists between the urban area and natural stone resources, and highlighting the role that stone has and had in culture and economic wealth of the region (Borghi et al. 2016).

From Roman times to the 18th century approximately, the most easily workable stone materials (such as marble and sedimentary rocks) were mainly exploited and used for valuable infrastructures and sculptures. Starting from the 19th century, thanks to the development of new technologies for quarrying and processing, also stones composed of harder silicate minerals have been progressively used as decorative elements. Currently, the façades and other architectural elements of historical buildings in Piemonte and especially in Torino, therefore, represent an open-air, petrographic collection where an attentive visitor can enjoy a feeling of both scientific and cultural character. For example, the petrographic description of ornamental stones of Torino has been the subject of several papers (e.g., Sacco 1907; Peretti 1937; Rodolico 1953; Chiari et al. 1992; Fiora et al. 2007). Recently, an updated catalogue of the most significant stone buildings of the city is reported by Borghi et al. (2014) and Gambino et al. (2019). However, there isn't currently an organic document that includes petrographic characterisation, provenance, geological framework and dissemination of Piemonte rocks. The previous approaches were limited to specific case history.~~silicate stones have been progressively used as decorative elements. The great variety of ornamental and building stones present in Piemonte is due to the extremely complex geological nature of the region. Indeed, in Piemonte region several different lithotypes can be~~

recognised; such lithotypes characterise the western portion of the Alpine metamorphic chain and the sedimentary basin that extends into the central-southern sector of the region, known as the Tertiary Piemonte Basin (Fig. 1).

The promotion and dissemination of historical and cultural stones among a wider audience are fundamental, not only to improve general knowledge on natural resources but also to enhance the self-consciousness of the deep connection between environment and exploitation, balancing both sustainability and cultural heritage (Dino et al. 2019). In the past, however, few scientific works described and improved this important economic and cultural resource (e.g. Barelli 1835; Jervis 1889; Sacco 1907; Peretti 1938; Rodolico 1953; Fiora et al. 2007).

RecentlyMore recently Piana et al. (2017a, b2017) drafted a complete interactive geological map of the Piemonte Region (GeoPiemonteMap Project) available as a WebGIS service. The GeoPiemonte Map was developed by the National Research Council CNR, Institute of Geosciences and Georesources of Torino (CNR - IGG), the Regional Agency for the Protection of the Environment of, ARPA Piemonte (Agenzia Regionale per la Protezione Ambientale - Arpa Piemonte), and the University of Torino (Department of Earth Sciences). Starting from this, Barale et al. (2020) realised the geolithologicalgeo-lithological map of the Piemonte ornamental stones at 1:250,000 scale with the aim to review the ornamental stone heritage of Piemonte at a regional scale. The map consists of a simplified lithological base, derived from the above cited GeoPiemonte Map, on which the ornamental stones are reported as punctual objects corresponding to their quarry sites. This new map, based on a thorough revision of the available literature and integrated with some unpublished original data, shows the location of the main quarries of historic and contemporaneous ornamental stones of the region. The stone materials, and their historical-architectural uses, are described in the map database (DB), properly designed to enhance the value of the stones in the cultural heritage.

This paper focuses on the description of the DBdatabase and the development of the map as a WebGISWeb GIS service. The WebGISWeb GIS service is hosted on the Arpa Piemonte geoportal, and allows interactive querying and download of the DBdatabase information.

2. The geological diversity of Piemonte

The great variety of ornamental and building stones present inof Piemonte (e.g. Catella 1969) is due to the extremely extreme geological diversity of the region, which encompasses rock types pertaining to very different geological contexts (e.g., Piana et al. 2017a; Piana et al. 2017b). The Piemonte area underwent a long geological evolution, resulting in a complex geological nature of the region. Indeed, in the Piemonte several different lithotypes can be recognised; such lithotypes characterise setting characterised by the western portionsector of the Alpine chain (of Cenozoic age), and made up, in its axial part, mostly of high pressure and low temperature metamorphic rocks of both continental and oceanic origin; these rocks underwent an Eocene subduction event followed by a continental collision event (e.g. Dal Piaz et al. 2003; Dewey et al. 1973; Handy et al. chain and 2010). The metamorphic grade decreases outward from the axial part of the sedimentary chain both toward its internal (Padane) and outer (Suisse-French) side, where low- to non-metamorphic rocks, including Mesozoic sedimentary successions of the Tertiary Piemonte Basin (TPB) croppingEuropean and Adriatic continental margins, crop out in. Since the central-southern sector of the region.

Piemonte is a region characterised by a great geodiversity, with a notable variety of geological contexts that characterises the different orographic elements present, such as the mountain chains of the western middle Eocene, synorogenic sedimentary basins developed in front of the Alps (Graian, Cottian, Maritime and Ligurian) and of the northern -

Apennines, the hill systems of the Langhe and Monferrato, the moraine systems at the outlet of the Alpine valleys and the large foothill fans that slope down into the Po Valley alluvial plain (Piana et al. 2017a) (Fig. 1).

This complex geo-diversity has aroused considerable interest over the last two hundred years, not only scientifically but also from a geo-touristic ~~orogen~~ and socio-economic point of view. This geological complexity determines the geo-environmental constraints on the use of the territory, as well as the distribution and management of surface (stone materials) and subsoil (water and geothermal) georesources.

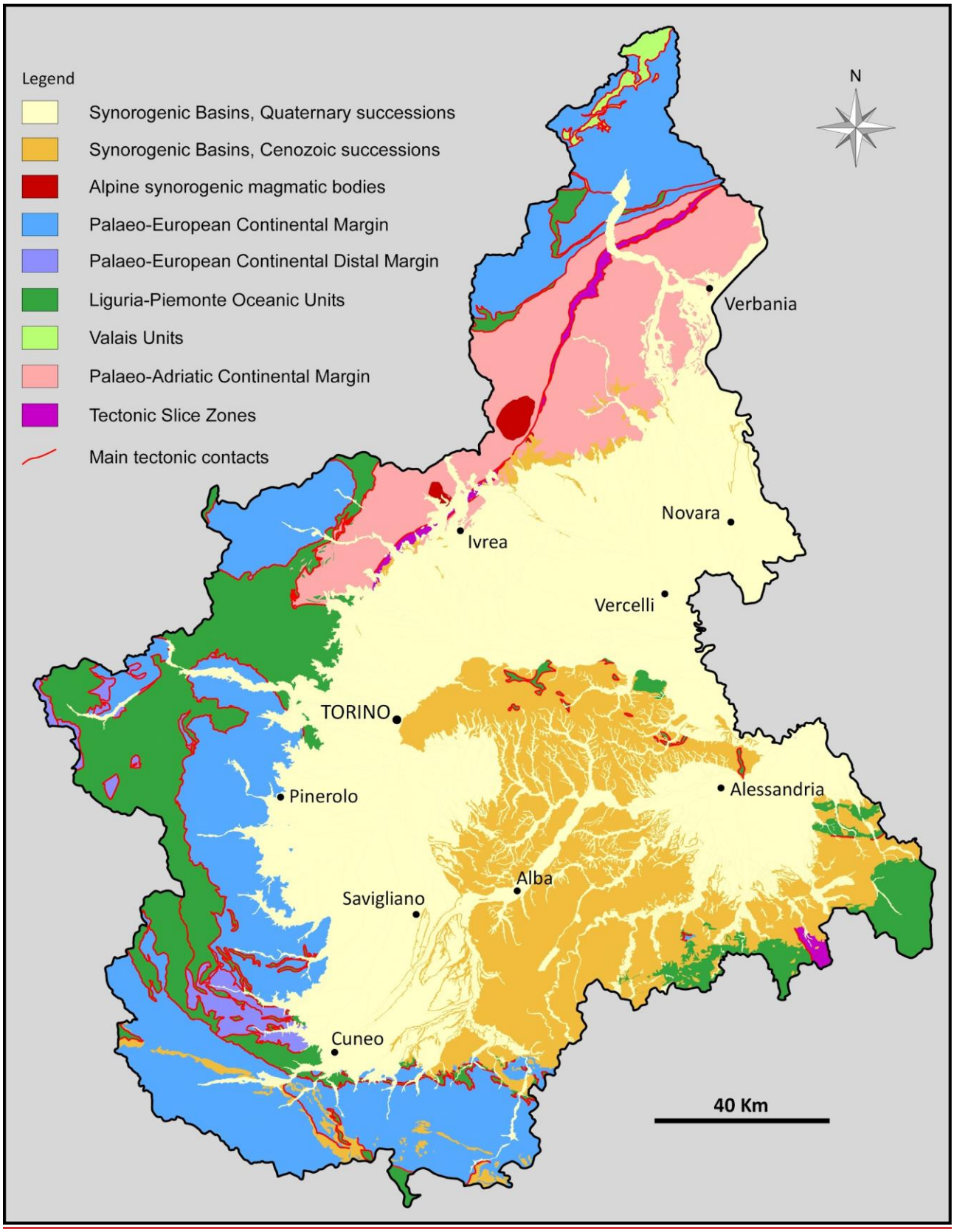


Fig. 1 Scheme showing the present distribution of the palaeogeographic domains of the Piemonte region (from Piana et al. 2017a, b)

The complexity of the geology of Piemonte is the result of a continuous geodynamic process which, since the Jurassic, led to the formation of two continental 'passive' margins: the 'Palaeo-European Continental Margin' and the 'Palaeo-Adriatic Continental Margin', and two zones of oceanic pertinence named Liguria-Piemonte Oceanic Units and Valais Units (Dal Piaz 1999; Dal Piaz et al. 1972; Dewey and Bird 1970; Dewey et al. ~~were progressively involved in the overall~~1973; Handy et al. 2010; Mohn et al. 2010). The 'Palaeo-European Margin' concept is here used sensu Handy et al. (2010) and Mohn et al. (2010), where the Briançonnais Domain is viewed as an isolated part of the European continental margin placed between the Valais Units and Liguria–Piemonte Oceanic Units (for the northern part of Piemonte) and a portion of the hyperextended European continental margin, named 'Palaeo-European Continental Distal Margin' (for the south-western part). The 'Palaeo-Adriatic Continental Margin' concept is here considered in the sense of Stampfli et al. (1998), referring solely to the continental margin of the 'Adriatic plate sensu stricto'. It consists of tectonic units which suffered the Alpine metamorphism under eclogite facies conditions (Sesia Lanzo Zone) or greenschist-blueschist facies conditions (Dent Blanche System) separated from the Southalpine Alpine Domain by the Insubric Line. The Palaeo-Adriatic Continental Margin was intruded in the Oligocene by the Alpine synorogenic magmatic bodies, among which two important plutons (Valle Cervo Pluton and Brosso-Traversella Pluton) and by calcalkaline volcanic suite (Biella volcano-sedimentary Suite), discordant with the main Alpine structures.

The NW Alpine chain is subdivided into three main structural domains (see Beltrando et al. 2010; Dal Piaz et al. 2003; Pfiffner et al. 1997; Schmid et al. 2004 for a review).

(i) an internal domain (Southalpine Domain) belonging~~system. For a more detailed geological setting the reader can refer~~ to the upper plate of the collisional system (Adriatic plate) and only partially involved in the Alpine orogenic process. This domain is made of Variscan and pre-Variscan basement with middle (Serie dei Laghi Unit) and lower (Ivrea-Verbano Zone) continental crust and upper mantle rocks, which underwent minor Alpine metamorphism, intruded by Permian magmatic bodies (Permian Magmatic Complex of "Graniti dei Laghi": Mottarone-Baveno Pluton and Alzo-Roccapietra Pluton), and covered by Permian volcanic rocks, volcaniclastic deposits and a Mesozoic sedimentary succession. This domain is bounded by a Tectonic Slice Zone (Canavese Zone: ZC), a narrow, wide band a few kilometres and about 40 km long, delimited by two faults, approximately NE-SW trending, named the Internal and External Canavese Lines. The ZC consists of Permian granites and is covered by carbonate succession of Mesozoic age.

(ii) a central (axial) part of the orogenic system (partially corresponding to the Penninic Domain Auct.), bounded by two main tectonic discontinuities, the Insubric-Canavese Line on the inner side and the Penninic Front on the outer side. It is made up of rock units with different origins involved in the Alpine orogenic prism and thus metamorphosed (Beltrando et al. 2010). These units originally belonged to the Liguria-Piemonte Oceanic Units and to portions of the Palaeo-European (Briançonnais Domain, Lower and Upper Penninic Domains) and Palaeo-Adriatic (Austroalpine Domain) continental margins. The Upper Penninic Domain correspond to the so-called Internal Crystalline Massifs represented by the Monte Rosa, Gran Paradiso and Dora-Maira units, equilibrated under eclogite facies metamorphic conditions. They mainly consist of mono- and poly-metamorphic silicate-bearing rocks as micaschists and orthogneisses and minor meta-carbonate cover of Mesozoic age (e.g. De Giusti et al. 2004 and references therein). The Briançonnais Domain is further divided into an internal zone, including a polymetamorphic basement, a monometamorphic basement of Permo-Carboniferous age and a meta-sedimentary cover of Mesozoic age (Internal Briançonnais Domain) and an external zone made up of Mesozoic carbonate successions of the Palaeo-European Continental Margin (External Briançonnais Domain).

The Lower Penninic Domain represents the deepest tectonic element in the axial sector of the Alpine chain and includes the Antigorio, the Monte Leone and the Moncucco-Orselina-Isorno units.

The units of the axial sector, during their subduction at depths of 50-100 km (at approximately 65-40 Ma) and subsequent exhumation (at approximately 35-20 Ma), underwent metamorphic transformations ranging between the high and very high pressure eclogitic facies and the low-pressure, low-temperature greenschist facies.

(iii) an external domain (i.e. placed on the European side of the Alps, mostly in France and Switzerland), belonging to the lower plate of the collisional system and corresponding to the Helvetic, Dauphinois, Provençal and (partially) to the External Briançonnais domains of the geological literature. This domain consists of a Variscan polymetamorphic basement with Carboniferous to Permian sedimentary successions and intrusive bodies (Argentera Massif), Mesozoic sedimentary covers and Cenozoic synorogenic deposits, which underwent anchizone to lower greenschist facies metamorphism.

The central sector of the Piemonte region is characterised by the presence of sedimentary successions deposited, from the late Eocene to the Quaternary, in Synorogenic Basins (Cenozoic successions and Quaternary successions in Fig. 1), i.e. in basins formed during and in relation to the geodynamic conditions that led to the formation of the orogenic systems currently exposed in the Alpine and Apennine chains. These basins, which can be considered an integral part of the Alpine-Apennine orogenic system, have very well recorded the geological evolution that determined their formation. The successions of these basins, uplifted during the Cenozoic, constitute the current reliefs of the Langhe, Alto Monferrato, Monferrato and the Torino Hill. The Oligocene-Miocene succession was deposited in a basin known as Tertiary Piemonte Basin (TPB) consisting of lithostratigraphic units correlatable through the different structural domains of the TPB.

The above described subdivisions of the Alps-Apennines orogenic system inspired the Legend of the GeoPiemonte Map (Piana et al. 2017a, b) and related DB and allowed the elaboration of a new Lithological Map, reported in Barale et al. (2020), where the number of geological classes were reduced in order to have a simplified geo-lithological representation. In this work, a further simplification of the Piemonte geological Map is given (Fig. 2) to allow a concise graphic representation of the lithological variety of the region, suitable for classifying the ornamental stones, as well as a robust Data Model to be implemented by thematic data regarding cultural heritage and economic employment.~~2017).~~

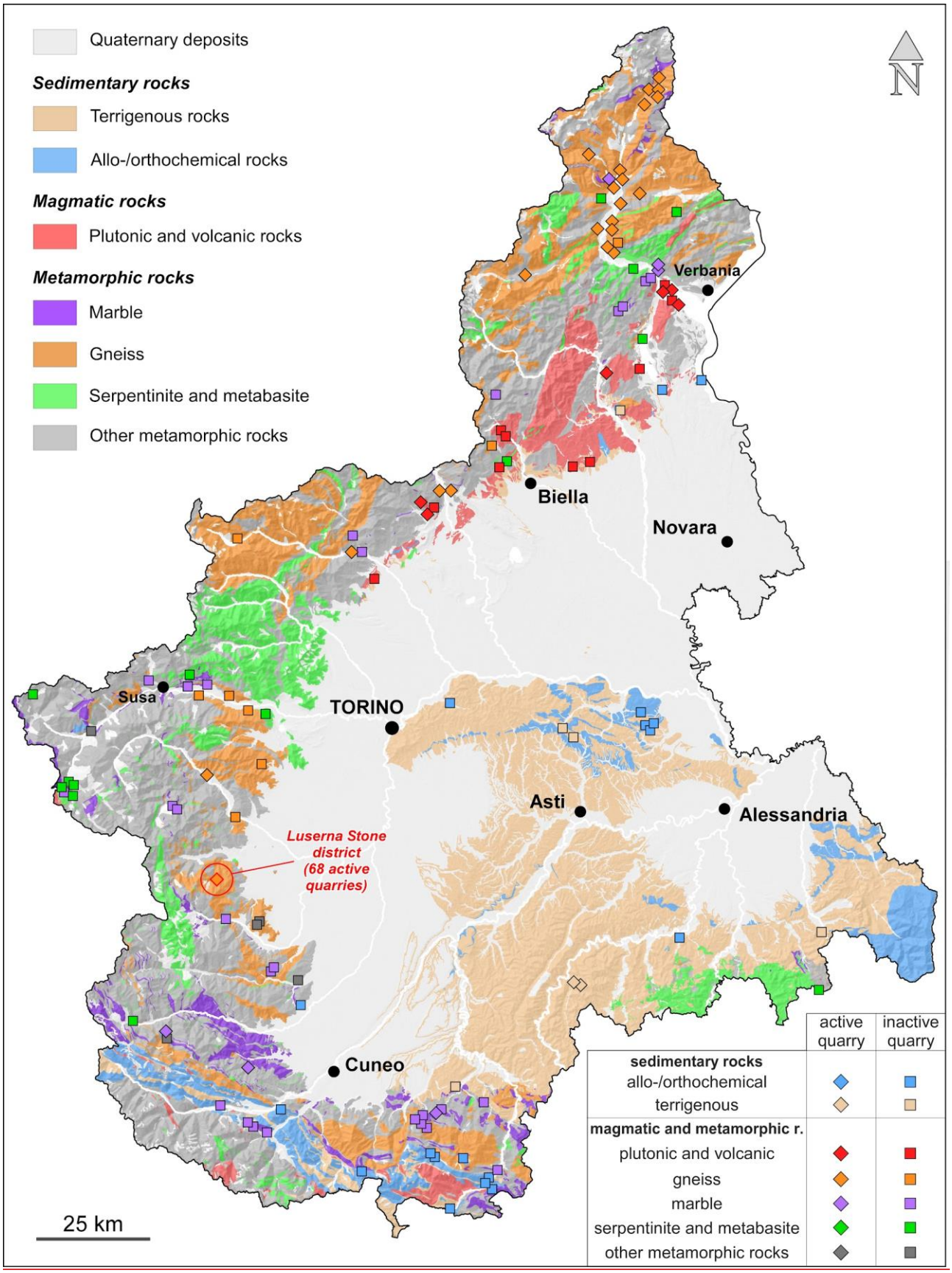
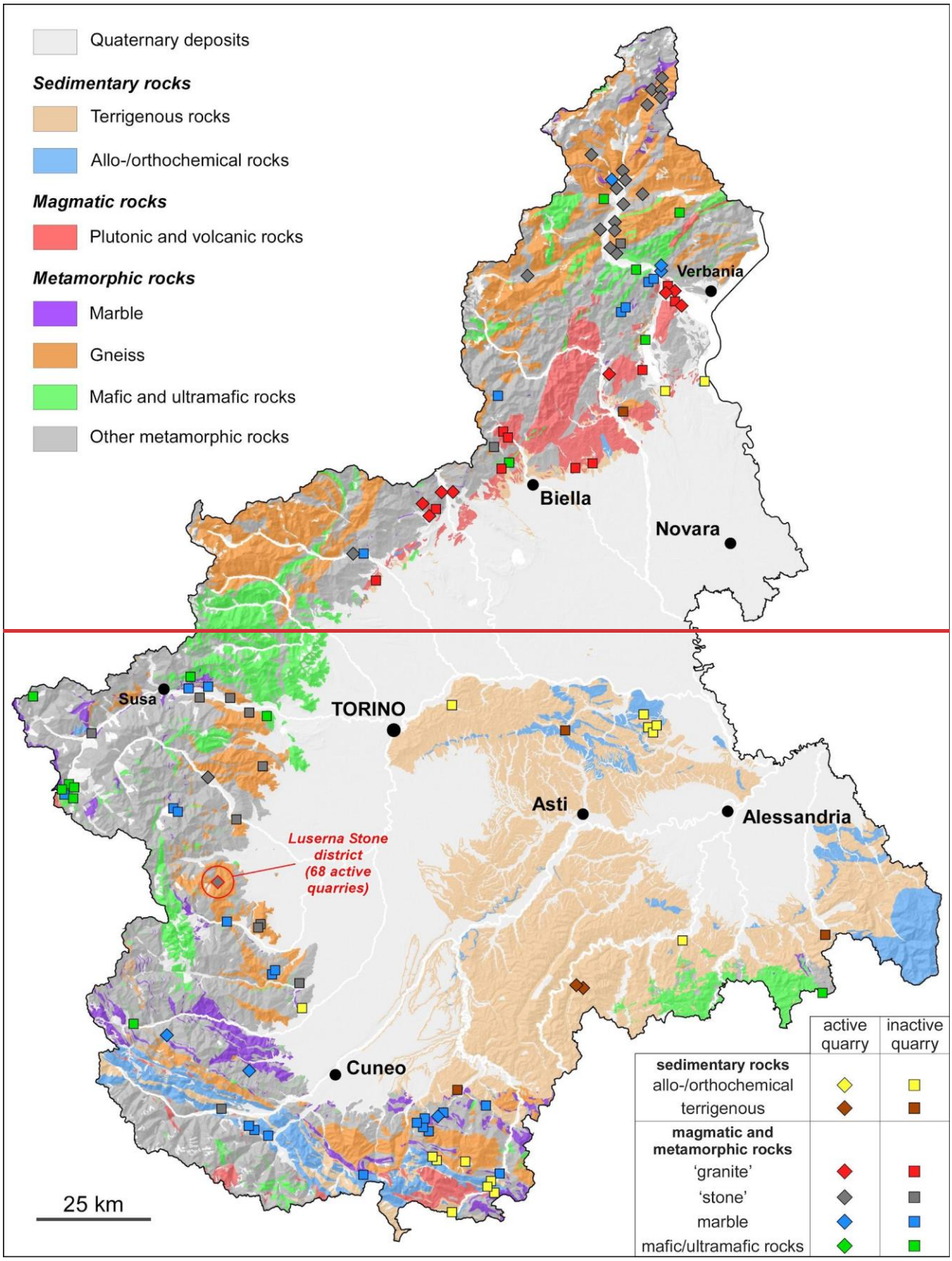


Fig. 2~~Starting from the GeoPiemonte Map Legend, a concise graphic representation of Piemonte region lithology, suitable for classifying the Ornamental Stones, has been defined (Fig. 1).~~



~~Fig. 1~~ Simplified lithological map of Piemonte region based on genetic and compositional criteria. The position~~Geographic distribution~~ of the quarries of the Piemonte ornamental stones is~~are~~ also reported. The legend at the bottom right indicates active and inactive quarries with different symbols~~ and is according to the ornamental stone classification of Barale et al. (2020)~~

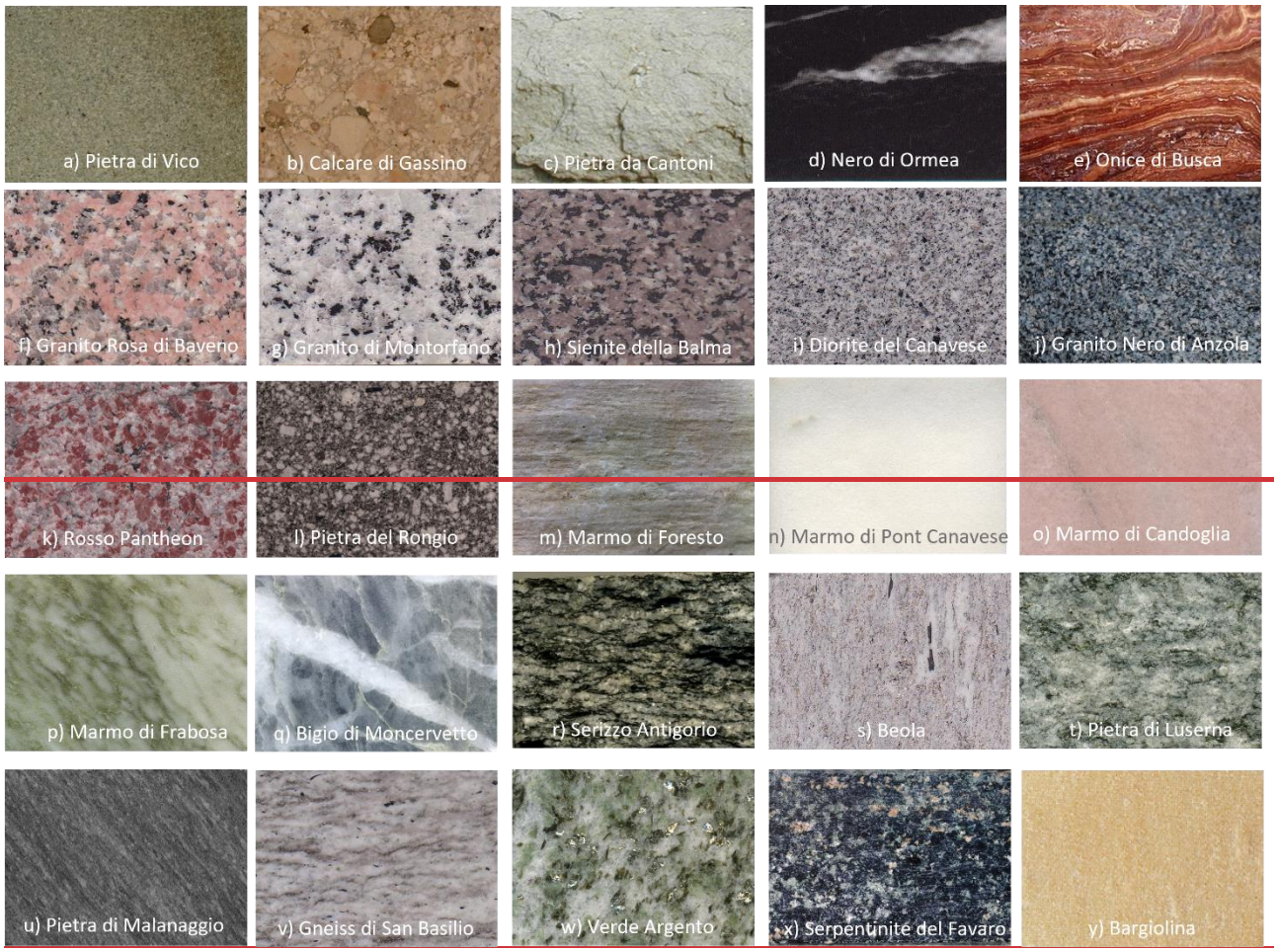
For sake of simplicity, the rocks of the geological units cropping out in the Piemonte region have been splitted into the three large groups of sedimentary, magmatic and metamorphic rocks.

Furthermore~~Thus~~, the sedimentary rocks have been divided into *terrigenous* and *allo/orthochemical rocks*, according to the Folk classification (1981), which provides for a subdivision conforming to the main sedimentary components~~their origin~~; the magmatic rocks have been organised in *plutonic* and *volcanic rocks*, according to the emplacement mechanisms and to the IUGS (International Union of Geological Sciences, Streckeisen et al. 2002),~~,~~ and finally, the metamorphic rocks have been splitted into~~in~~ *marbles* (metamorphic rocks of carbonate composition), *gneisses* (medium-high grade metamorphic rocks of felsic composition), *serpentinite and metabasites* ~~*mafic/ultramafic rocks*~~ (metamorphic ~~and magmatic~~ rocks of mafic and ultramafic composition) and *other metamorphic rocks* (e.g. quartzites, calcschists),~~,~~ which are not comprised into the previous~~these~~ categories, according to the Simple Lithology concepts, defined by the IUGS Commission for Geoscience Information (CGI) - Geoscience Terminology Working Group and according to Fettes and Desmons (2007) and Barale et al. (2020).

In conclusion, the~~. The~~ Piemonte rocks have been grouped (using strictly lithological criteria) into seven main legend boxes. In this way, petrographically similar rocks are now grouped together even if characterised by very different geological histories, ages and paleogeographic origins.

3. Historical Piemonte ornamental stones and their use

In the following the main ornamental stones used in Piemonte are reported and described separately for each of the above described lithological classes. The classification of the rocks follows the legend of ~~Legend of Fig. 1 and the representative images of the more used historic stones of Piemonte are reported in Fig.~~Fig. 2.



~~Fig. 2 Representative images of the main ornamental stones quarried in Piemonte region~~

3.1 Sedimentary rocks

3.1.1 Terrigenous rocks

The main ~~-~~terrigenous rocks used as ornamental stones are Miocene arenites of the TPB~~Tertiary Piemonte Basin~~: Pietra di Langa (Langa Stone), Pietra di Vico and Pietra di Montaldero (Vico Stone, Montaldero Stone).

~~–~~The Pietra di Langa is a turbiditic~~turbidite~~ sandstone of the Cortemilia Formation (late Burdigalian - early Langhian) used ~~-~~in Romanic (e.g. Madonna della Pieve church~~Church~~ of Cortemilia – Cuneo) and Renaissance (e.g. Santa Maria Annunziata church in Roccaverano – Asti) ages.

The Pietra di Vico (Vico Stone, Fig. 3a~~2a~~) is a yellow to grey arenite of the San Paolo Formation (Burdigalian) deposited in a shallow water marine environment, characterised by abundant dolomite cement. It was employed in the external cladding of the Sanctuary of Vicoforte (Cuneo) (Fig. ~~3a).~~4a). It is a monumental church from the 18th century, among the most important in Piemonte, whose dome, with an elliptical horizontal section, is the largest of this shape in the world.

The Pietra di Montaldero is a bioclastic arenite of Burdigalian age used for the construction of the roman city of Libarna, near Serravalle Scrivia (Alessandria), and in many civil and religious buildings of the Scrivia Valley (Alessandria).

3.1.2- Allochemical and orthochemical rocks

In the antiquity numerous white and coloured limestones were used in Piemonte. Most of the white limestones were quarried from the TPB~~Tertiary Piemonte Basin~~ succession. The most famous quarried material is the Calcare di Gassino (Gassino Limestone, Fig. 3b~~2b~~, Campanino and Ricci 1991), a biocalcirudite rich in red algae~~molluses~~ and Larger Benthic Foraminifera (LBF) (mainly ~~macroforaminifera (~~*Nummulites*) of late Eocene age~~,~~ and cropping out in the Torino Hill. It was used as ornamental stone in the 18th–19th centuries in Torino in historic buildings such as Palazzo Carignano, Valentino Castle, and finally the Basilica of Superga ~~-~~(Fig. 4b), a religious complex located on the Torino Hill and designed by the baroque architect Filippo Juvarra.~~3b).~~

Another historical limestone is the Pietra da Cantoni (Cantoni Stone) (Fig. 3c~~2c~~), a glauconite-rich biocalcarenite of Burdigalian age, quarried ~~-~~in the Monferrato ~~area~~ and used since Roman times. It was widely used during the Middle Ages in the Monferrato area (Duomo di Casale, Romanesque country churches) and Torino Hill (Abbazia di Vezzolano).

An important historical allochemical sedimentary material used in the Alessandria province is the Pietra di Visone (Visone Stone). It is a Burdigalian biocalcarenite-biocalcirudite rich in LBF (*Operculina* and~~macroforaminifera (Amphistegina,~~ *Miogypsina*), deposited in a temperate carbonate ramp, cropping out in the Alto Monferrato. It was used since Roman times, and in the Renaissance period in the Alessandria province (e.g. Acqui Terme Cathedral and Basilica of Santa Croce in Bosco Marengo).

Coloured limestones were exploited from the Triassic-Jurassic succession of the External Briançonnais Domain and largely used ~~-~~as ornamental stones (Persichini, Portoro di Nava, Nero di Ormea) in Torino in the 18th-19th century.

The term "Persichini" (derived from the old Italian “persica”, meaning peach, for their reddish-pink~~pinkish~~ colour) (Fig. 3d) is used for Upper Triassic-Lower Jurassic rocks interpreted as a product of an emersion during the Early Jurassic rifting phases of the Alpine Tethys (De Carlis and Lualdi 2008). They consist of polygenic and polychrome matrix~~-~~ to clast-supported dolomite breccias, with a dolomitized matrix rich in iron oxides, more or less intensely recrystallised. These breccias, historically known as Persichino di Garessio, Persichino di Corsaglia and ~~-~~Breccia di Casotto (Casotto Breccia) were widely employed for columns in Torino and surroundings (Basilica of Superga, Gran Madre di Dio church~~Church~~ in Torino and Sant’Uberto Chapel at Venaria Reale, Torino, ~~-~~Badino et al. 2001).

Among the coloured limestones, the Nero di Ormea (Fig. 3e~~2d~~) is a recrystallised~~recrystallized~~ black limestone derived from sediments deposited in a restricted platform environment (Calcari di Rio di Nava, Middle Jurassic). The structure can be uniform (Nero di Ormea) or veined (Portoro di Nava variety). This rock was widely used in the internal decorations of Baroque churches.

The only orthochemical rock used in Piemonte as ornamental stone is the Onice di Busca (Busca Onyx) (Fig. 3f~~2e~~). It was exploited in the past from metre-thick bodies of speleothems (calcite alabaster) filling fissures within the marbles of the Dora~~-~~-Maira Unit. The Onice di Busca found extensive use in the interior decorations of many Baroque churches in Torino (Marengo et al.~~. The exploitation began in 1640-1650, but the greatest period for its exploitation was between the second half of the 18th century and the middle of 19th century, when the rock was exported to North and South America (Marengo et al.~~ 2019). One of the most impressive examples of application of Onice di Busca is in the church of San Filippo Neri, the largest church in Torino, where this material was used to build the columns that delimit the nave, for the balustrades and for the six columns of the high altar.

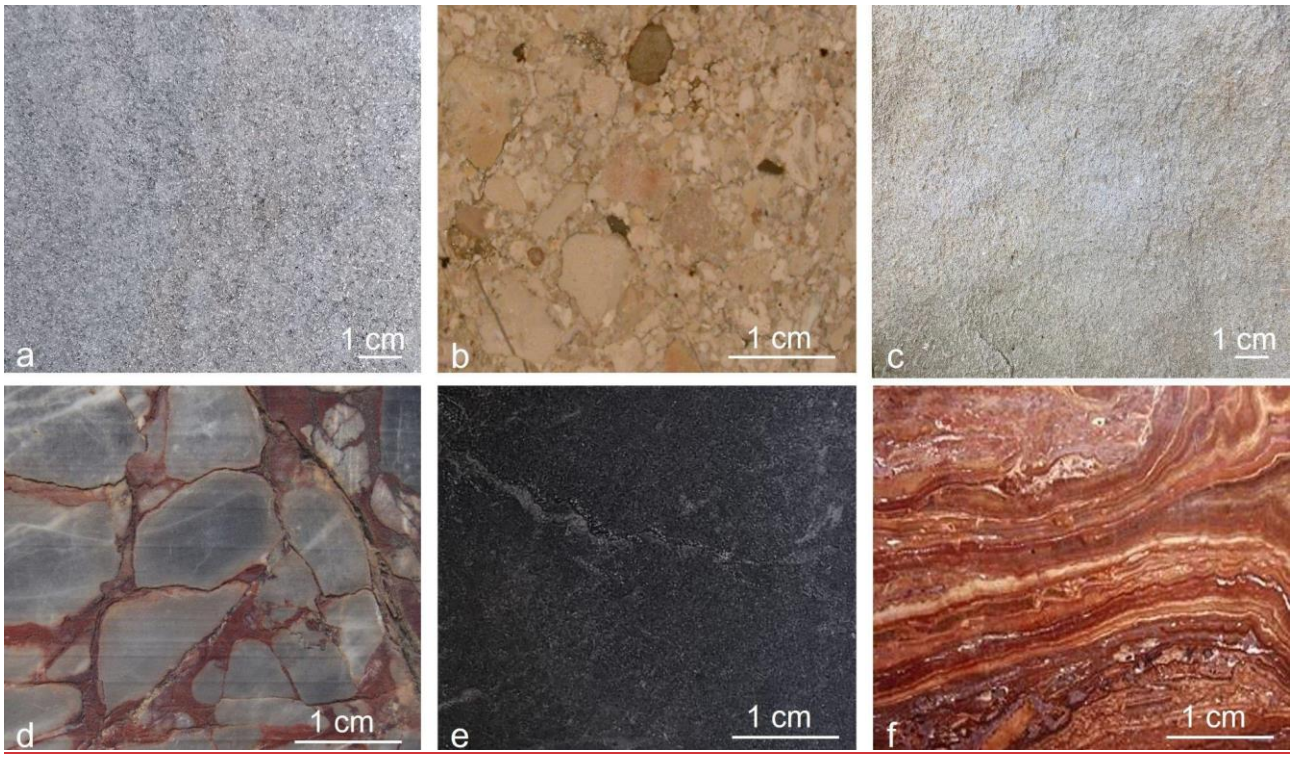


Fig. 3 Macrophotographs of the main sedimentary ornamental stones exploited in the past in Piemonte region: a) Pietra di Vico; b) Calcare di Gassino; c) Pietra da Cantoni; d) Persichini; e) Nero di Ormea; f) Onice di Busca

3.2 Magmatic rocks

3.2.1 Plutonic rocks

The magmatic rocks, although not extensively~~widely~~ occurring in Piemonte, show different varieties of ornamental stones.

The Mottarone-Baveno Pluton~~pluton~~, which is located~~placed~~ between the Toce River and Maggiore Lake, extends~~is extended~~ at the surface for ~~-~~about 30 km^2. The lower portion of this pluton consists of~~is represented by~~ white granite, while the upper part is formed by pink granite (Caironi et al. 2006). The first traces of granite exploitation, mainly from "pedrere" (areas showing the presence of blocks of granite transported by glaciers) and ~~-~~small open~~-~~air quarries, are dated to the 15th century, initially in the Montorfano area and then also in Baveno and Mergozzo quarry sites. From the 16th century the exploitation of granite increased more and more, thanks to excavation by means of "cugnere" (a rock~~-~~splitting wedge). From the 19th century the quarrying techniques, thanks to the employment of explosives, became more organised and similar to the present ones; such improvement guaranteed the excavation of the material not only for a local supply, but also for a national one (eg. columns of Via Roma~~ street~~ in Torino, and the 82 columns of the Basilica di San Paolo fuori le Mura in Roma). The quarries of this material are historically and culturally the most important in the Verbano – Cusio – Ossola area (VCO) (Dino and Cavallo 2014).

In particular, the Granito Rosa di Baveno (Baveno Pink Granite, Fig. 5a~~2f~~) is undoubtedly one of the most widely used ornamental stones in Piemonte. It shows a medium to fine grain size and it is characterised by K-feldspar, quartz, plagioclase and biotite, showing a typical pink colour due to the alteration of ~~-~~K-feldspar crystals. This stone derives from the Permian Magmatic Complex~~a composite complex~~ of "Graniti dei Laghi"~~plutonic bodies~~ (Mottarone – Baveno Pluton~~pluton~~) of ~~early~~ Permian age (Boriani et al. 1992) that intruded, at a shallow depth, the Southalpine

DomainSouthern Alps basement of the Serie dei Laghi Unit. This valuable rock was quarried and worked since the 16th century, but only in the 19th century the number of quarries increased more and more, representing one of the major economic activities in the area. The most important –uses– of the Granito Rosa di Baveno in the city of Torino are represented by the columns of the Mole Antonelliana, the façade of the San Carlo churchChurch, and the columns and pilasters of the 19th century façade of Palazzo Carignano. Another commonly employed plutonic rock exploited in the VCOVerbano-Cusio-Ossola-Sesia Valley quarry district is the Granito Bianco dei Laghi. It is similar to the Granito Rosa di Baveno, from which differs by the overall light grey colour, due to the white colour of the K-feldspar crystals. Depending on the site of origin, different varieties of granite can be recognisedrecognized: the "Granito di Montorfano" (Fig. 5b2g), characterised by the presence of xenoliths and "spots" of iron oxides, and the "Granito di Alzo", recognizable by the absence of mafic xenoliths. One of the first uses of this granite can be observed in the old village of Montorfano, located exactly above the current main quarry (well-known as Cavadonna, original name of the quarry). In this village the granite, originally exploited from local "pedrere",– was used for every structural element and in particular for the dry masonry of the spectacular Romanesque church of San Giovanni, built between the 11th and 12th centuries (Fig. 4c3c).

The Alzo-Roccapietra Plutonpluton crops out between the lower Sesia Valley and the Orta Lake. The historic quarry sites, no longer exploited due to problems related to the large and heavy Quaternaryquaternary cover and landscape restrictions, were placed near Alzo and Boleto villages, on the Orta Lake (Novara), and Roccapietra village, in the lower part of Sesia Valley (Vercelli). The granite extracted was widely used for historic buildings in Torino, in particular in the paving of Via Roma and in the stone balustrade of the Umberto I bridge over the Po Riverriver. It was also used in the chapels of the Sacro Monte of Varallo (Unesco World Heritage Site) in the Sesia Valley.

The Sienite della Balma (Balma Syenite, Fig. 5c2h) is quarried from the Oligocene Valle Cervo Plutona pluton cropping out a few kilometres north of Biella, in the Cervo Valley, covering an area of about 35 km^2. According to Bigioggero et al. (1994), the pluton is compositionally zoned and consists of monzogranitic rocks in the core surrounded by a discontinuous portion of syenitic rocks and, finally, by a wide rim of monzonitic rocks. Currently there are no active quarries, but ten abandoned quarries are located in among the villages of Rialmosso, Piedicavallo, Balma, Campiglia Cervo, Rosazza and Oropa (Fiora et al. 2000). The Sienite della Balma shows a typical grey-violet colour, due to the K-feldspar, a medium grain size and a well–developed magmatic flow fabric. There are many historical uses of this stone. In Torino it is possible to recognise its presence in several buildings and infrastructures such as: the monument of Emanuele Filiberto Duke of Aosta in Piazza Castello square, the pavement of many blocks of Via Roma, the road pavement of the Vittorio Emanuele I and Umberto I bridges, the steps of San Massimo church. In Ivrea, the Olivetti office building (1960 – 1963) is largely covered by this stone.

The Diorite del Canavese (Canavese Diorite, Fig. 5d2i) derives from the Oligocene Brosso-Traversella Pluton, which crops out in the Canavese area over about 5 km^2 (Peretti 1938). The rock is exploited along the Chiusella Valley (Torino). Currently there is only one active quarry in Traversella. The Diorite del Canavese shows a granular texture and a colour which varies from light to very dark grey depending on the grain size and on the percentage of maficfemic minerals, represented by amphibole, biotite, and rare pyroxene. Among the sialic minerals, plagioclase mainly occurs in addition to rare quartz and poikilitic K-feldspar. This rock was widely used in Torino for columns in the Sant' Emanuele block in Via Roma, the paving of ancient passageways for cars and carriages in Piazza San Carlo, and the road paving of the Vittorio Emanuele I and Umberto I bridges.

Another interesting intrusive rock is the commercially so-called Granito Nero di Anzola (Anzola Black Granite, Fig. 5e~~2j~~). This ornamental stone, no longer quarried, encompasses a wide~~large~~ range of basic to ultrabasic rocks (from diorite to gabbro – norite up to websterite) of Permian age (Peressini et al. 2007)~~-~~ intruded in the Ivrea-Verbano Zone. It was the only "black granite" quarried in Italy. The extraction of the rock began between 1906 and 1910, with the opening of two quarries at Anzola d'Ossola (Peretti 1938), just upstream of Ornavasso along the middle Toce Valley, in the VCO~~Verbano-Cusio-Ossola~~-Sesia Valley. The rock was used in Torino for part of the flooring of Via Roma and for the entrance steps of the Santissima Annunziata church. Pebbles of fluvial origin composed of this rock (diorites and gabbros in particular) were used by Romans for the construction of the amphitheatre (Fig. 4d~~3d~~) in Eporedia (current Ivrea) in the 1st century AD (Storta et al. 2022b).

Among the intrusive magmatic rocks worthy of mention is the Rosso Pantheon (Fig. 5f~~2k~~), a Permian granite belonging to the Canavese Zone. It is an isotropic intrusive magmatic rock with homogeneous medium grain, typified by the intense red colour of orthoclase. The paragenesis is completed by plagioclase, quartz, and biotite partially replaced by chlorite. The Rosso Pantheon is a poorly used ornamental stone: the only quarry of this stone was located near Belmonte (Valperga municipality, Torino), where an attempt was made, at the beginning of the 20th century, to start an important quarrying activity. The Rosso Pantheon was used, between the two World Wars, for monumental buildings in the rationalist style of the period, such as, for example, in the Principi di Piemonte Hotel in Torino (Müller 1990).


a
b
c
d

Fig. ~~43~~ 4 Main examples of employment of Piemonte dimension stones in historic buildings: a) Sanctuary of Vicoforte built in Pietra di Vico; b) ~~colonnade of the pronaos of the~~ Basilica of Superga with several elements in Calcare di Gassino; c) Romanesque church of San Giovanni in Montorfano village built with the Granito di Montorfano; d) Eporedia (ancient Ivrea, Torino province) amphitheatre wall mainly built with Diorite and Gabbro variety of the Granito Nero di Anzola

3.2.2 Volcanic rocks

In the Canavese-Biellese area, several metre-thick dykes of subvolcanic porphyritic rocks are intruded in Permian volcanites of the Southalpine Domain, as Pietra del Rongio (Rongio Stone). The Pietra del Rongio (Fig. 5g~~2l~~) is a filonian rock with oligoporphyritic structure and microcrystalline groundmass. The phenocrysts consist of idiomorphic plagioclase and brown biotite in thin, usually oriented flakes. ~~The medium-fine grained groundmass consists of plagioclase, brown biotite, quartz and rare interstitial K-feldspar.~~ The rock was used in Castelletto Cervo (Biella province) for the masonry ashlars of the Cluniac Priory of San Pietro and Paolo (Compagnoni et al. 2015),~~-~~ an imposing monumental structure that belonged to one of the richest and powerful monastic foundations of the subalpine Middle Ages.

Finally, the Andesite del Chiavolino (Chiavolino Andesite) (Fig. 5h) belongs to the Oligocene "Biella volcano-sedimentary Suite~~suite~~". It is a fine-grained, ~~purplish~~ effusive magmatic rock with a porphyritic texture and seriate fabric; among the phenocrysts ~~it is possible to recognize~~ plagioclase, pyroxene, brown hornblende and biotite are recognised.~~-~~ The groundmass is dark grey-purplish in colour. This rock was used for some external ~~monolithic~~ columns of the façade

of the Basilica of Vercelli (Fig. ~~4a).~~ 7a).

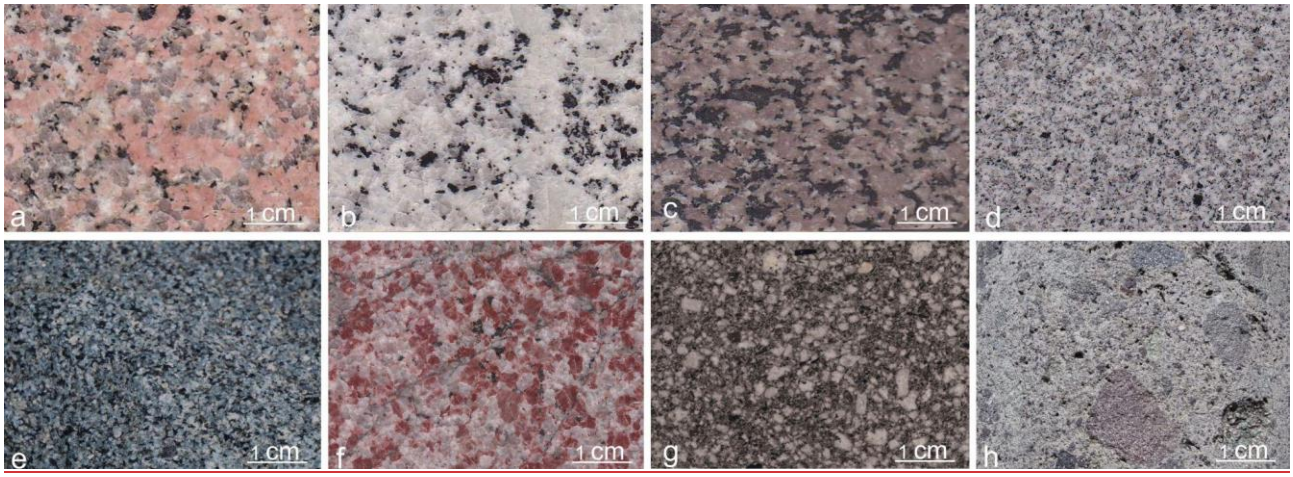


Fig. 5 Macrophotographs of some magmatic ornamental stones of Piemonte: a) Granito Rosa di Baveno; b) Granito di Montorfano; c) Sienite della Balma; d) Diorite del Canavese; e) Granito Nero di Anzola; f) Granito Rosso Pantheon; g) Pietra del Rongio; h) Andesite del Chiavolino

3.3 Metamorphic rocks

3.3.1 Marbles

Some of the oldest~~more ancient~~ and most significant white marbles of Piemonte are the Marmo di Foresto and Marmo di Chianocco (Foresto Marble and Chianocco Marble) (Fig. 6a~~2m~~), whose quarries exploit the metamorphic Mesozoic cover of the Dora--Maira Unit, in Susa Valley. These rocks were used in antiquity for the Arch of Augustus (Fig. 7b~~4b~~) built in Susa (Cottian Alps) in 8 b.c. by King Cozio following the peace with the Romans and dedicated to the Roman emperor (Borghi et al. 2009). The same materials were used in Augusta Taurinorum (Torino) for the statue of Augusto near the Porte Palatine (one of the gates of the Roman city walls) and more recently for church façades, statuary and other architectural and decorative elements, including the Renaissance façade of the Torino Cathedral and the Baroque façade of Palazzo Madama (Borghi et al. 2014; Gambino et al. 2019). Other white marbles extracted from the Dora--Maira Unit are the Paleozoic Marmo di Brossasco (Brossasco Marble) and Marmo di Prali (Prali Marble), used for the columns of the pronaos of the San Filippo Neri church and for the plinths of the entrance portal of the Royal Palace of Torino.

Marbles extracted from the Sesia -Lanzo Zone, such as the Marmo di Pont Canavese (Pont Canavese Marble) (Fig. 6b~~2n~~), were used from Roman Age, for example in the precious funerary Stele of the Gromaticus L.A. Faustus, exposed at the Garda Museum of Ivrea (Fig. 7c~~4c~~) (Storta et al. 2022a). It consists of a particular white marble table engraved in the 1st century A.D. It is a unique case of reproduction of the groma, a tool used for the operations of division and measurement of agricultural land for cadastral purposes. The groma is depicted only on this slab and on a Pompeian one from the 1st century A.D., in which it is however assembled and reproduced with less attention to details (Panerai 1984).

An~~Another~~ important historical marble is the Marmo di Candoglia (Candoglia Marble, Ivrea-Verbano Zone) (Fig. 6c~~2o~~), quarried for the exclusive use of the Veneranda Fabbrica del Duomo di Milano since 1387, the year in which Duke Gian Galeazzo Visconti obtained the authorization to exploit this stone. From that time this rock has been - and still is - employed uniquely for the construction and the maintenance of the Duomo di Milano (Milan Cathedral). The presence of rivers (Toce and Ticino) and the construction of canals (Navigli) guaranteed the direct and easy transport from the quarry area located in Ossola Valley (VCO) to Milano. Thus, the Marmo di Candoglia was preferred to other more famous Italian

marbles (e.g., Carrara marble) even if its textural features (coarse grain-size) were not fully suitable for statuary applications (Dino et al. 2019).

Another Piemonte ~~white~~ marble widely used in the past is the Marmo di Frabosa (Frabosa Marble, Internal Briançonnais Domain~~) (Fig. 2p~~), mainly used for statuary, given its easy workability due to its fine and homogeneous grain distribution. The Marmo di Frabosa was used in the external and internal decorations of the façades of some Baroque churches in Torino, such as the capitals in white variety and internal slabs in the "Verzino" (green) variety (Fig. 6d) of the Gran Madre di Dio church, the decorations of San Carlo and Santa Cristina churches, statues and pinnacles in the Palazzo Carignano and the pediment of San Filippo Neri church (Gambino et al. 2019). The black and "bigio" (grey) varieties were employed for the Chapel of the Holy Shroud (dome cladding). Another black marble is the Nero Nuvolato di Miroglio, employed in Torino for the atrium of the Galileo Ferraris Institute (former site of the Italian Standard Time) and for the Gran Madre di Dio church (internal decoration of the Ossario dei Caduti). Among the coloured marbles, the Bigio di Moncervetto (Fig. 6e~~2q~~) consists of a veined marble belonging to the Middle Triassic succession of the Internal ~~Ligurian~~ Briançonnais Domain (Badino et al. 2001). This marble shows a light grey colour and a fine grain, and is crosscut~~cross cut~~ by a network of large, coarsely-crystalline calcite veins. This is the only coloured marble still extracted in Piemonte from a quarry located at 900 metres a.s.l. on the left side of the Corsaglia Valley near Monastero di Vasco (Cuneo) (Badino et al. 2001). The origin of the quarries dates from the 14th century~~early 1300s~~, but it is only in the 16th and 17th centuries that a more intensive exploitation took place. The area was of particular interest for the Savoy kingdom (which in the past included the Piemonte region) quarrying activity, as many ornamental stones of different colour were exploited and used in lots of churches and palaces throughout the region such as the Sanctuary of Vicoforte and the Basilica of Superga (Badino et al. 2001). Finally, it is worth mentioning the Bardiglio di Valdieri (Fig 6f)~~,~~ a grey listed marble deriving from Cretaceous sedimentary successions of the Palaeo-European Continental Margin metamorphosed during the Oligocene by hydrothermal processes, and~~nature,~~ widely used from Roman times to the 18th century. It represents the most used listed marble employed in Piemonte, especially in the Baroque age.

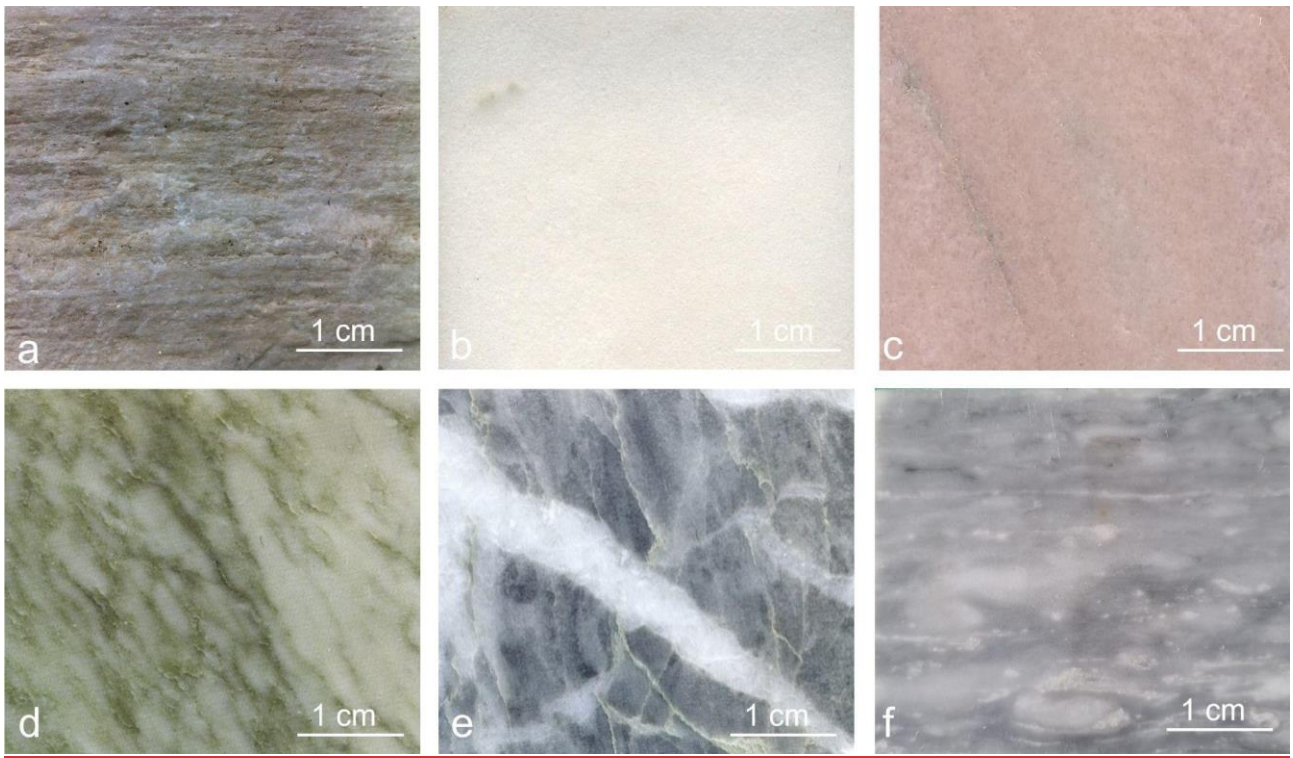


Fig. 6 Macrophotographs of marbles quarried in the past as ornamental stones: a) Marmo di Foresto; b) Marmo di Pont Canavese; c) Marmo di Candoglia; d) Marmo verzino di Frabosa; e) Marmo Bigio di Moncervetto; f) Marmo Bardiglio di Valdieri

3.3.2 Gneisses

This category of metamorphic rocks is mainly represented by gneissesgneiss coming from Western Alps -valleys. Among these, the rock most widely employed is certainly the Serizzo (Fig. 8a).2r). Geologically it belongs to the Antigorio Unit in the Lower Penninic Domain, which represents the deepest structural level of the Alps. The Serizzo, the most important dimension stone from VCO-Verbano – Cusio – Ossola – Sesia Valley district (Sandrone et al. 2004), consists of a large variety of orthogneisses characterised by "augen texture" (Sandrone et al. 2004). These rocks derive from Permian granites (270-280 Ma) and were pervasively equilibrated during the Alpine orogenic event under amphibolite facies conditions (Cavallo et al. 2004b). Three main varieties can be recognised: Antigorio, characterised by a darker colour, Formazza and Sempione. There is also a fourth variety, the Serizzo Monte Rosa, which, however, belongs to a different geological unit (Monte Rosa UnitNappe, Upper Penninic Domain). There are several active quarries, mostly located in the Antigorio and Formazza valleys. The Serizzo has been widely used over the centuries for local and non-local architectural uses: among the first the church of Santa Maria Assunta in Montecrestese (Verbano-Cusio-Ossola province-VCO) built between the 16th and 17th centuries. Not far from the church, on a small hillrise of land, stands the bell tower, which with its 67.5 metres high represents, representing the tallest bell tower in the Ossola area (Fig. 7d4d). Its great exploitation dates back to 20th century: it was largely used in northern Italy, as an external coveringcoverings for buildings, columns, plinths and flooring. In Milano it was used for the paving of XXV Aprile square, while in Torino the Serizzo Antigorio and the Serizzo Formazza were used for the flooring of the Porta Nuova railway station and in the construction of the 180 columns of the Via Roma arcades between Piazza San Carlo and Piazza Carlo Felice.

Another important metamorphic ornamental stone of the VCO-Verbano – Cusio – Ossola – Sesia Valley is the Beola (Fig. 8b), which belongs to the Lower Penninc Domain and, whose main varieties are "Grigia" and "Favalle"." (Fig. 2s). The term "Beola" refers to numerous varieties of orthogneiss with relatively similar mineralogical composition and characteristics coming from different lithological units in the area between Vogogna and Montecrestese. There are currently 7 active quarries of this material. The term "Beola" or "Bevola" originally derives from the name of the city where the largest number of quarries were present in the 15th century (Bevola, today Beura, Cavallo et al. 2004a). Most probablyWith a good probability, it is possible that the trade in this stone material began around the end of the 13th century, coinciding with the new possibility of navigatingsailing on the Grande Naviglio channel to Milano. On the other hand, it is also probable that the Romans had already exported the stone from the city of Beura, considering that the ancient Roman road crossed that location, as evidenced by an epigraph from 196 AD sculpted near Vogogna (Cavallo et al. 2004a). In addition to contemporary building cladding, flooring and street furniture, interesting historical examples of applications with Beola are the 15th century village and the castle of Vogogna (VCO province).

A further important metamorphic stone, being one of the most important materials used in the city of Torino, is the Pietra di Luserna (Luserna Stone, Fig. 8c2t). It is an orthogneiss belonging to the Dora-–Maira Unit, derived from Permian plutonic rocks. The Pietra di Luserna shows a light grey colour and a good fissility, which makes itbeing easy to split the rock along the schistosity planes. The rock crops out over an area of about- 50 km^2 in the Cottian Alps, at the border between Torino and Cuneo provinces. The Pietra di Luserna quarries (49 open quarries in 2023; Regione Piemonte 2023), located at altitudes between 900 and 1500 m a.s.l., are in Bagnolo Piemonte, Rorà and Luserna San Giovanni

municipalities. The Pietra di Luserna was used for the dome of the Mole Antonelliana, the symbol of Torino, for the paving of many squares and streets in the historic centre of Torino, for the façade of the Automobile Museum, for the pavements of the Vittorio Emanuele I and Umberto I bridges, which cross the Po River~~river~~.

A variety of slightly darker orthogneiss is the Pietra di Malanaggio (Malanaggio Stone, Fig. 8d~~2u~~), an amphibolic - biotitic orthogneiss intruded in the crystalline basement~~monometamorphic graphite-bearing sequence~~ of the Dora--Maira Unit. The quarrying activities started in the early 19th century with the opening of five quarries in the territory of Porte and Perosa Argentina (Chisone Valley~~)),~~ and ended after World War II due to the low request of stone materials and the decrement of manpower. There is only one open quarry in the village of Brandoneugna (Chisone Valley, Torino), where the so-called "Pietra di Perosa" (Perosa Stone) is exploited.

In the past, the lower Susa Valley (Torino) was characterised by the presence of numerous quarries for the exploitation of gneisses of the Dora-Maira Unit~~gneiss~~, namely the Gneiss di Borgone, Gneiss di Vaie, Gneiss di Villar Focchiardo and Pietra di San Basilio (Borgone, Vaie and Villar Focchiardo Gneiss, San Basilio Stone) (Barisone et al. 1992). The discovery of prehistoric objects near Vaie quarry suggests that these materials were employed during the Bronze Age; they were certainly used during the Roman age (Fiora and Gambelli 2003). In particular, the Pietra di San Basilio (Fig. 8e~~2v~~), corresponding to the historic Gneiss di Villar Focchiardo, consists of a tourmaline-rich leucocratic orthogneiss, and is light grey in colour. It is characterised by a granitic composition and shows a foliation defined by mica lamellae and by the orientation of tourmaline blasts (Borghi et al. 2016). In the~~The~~ Exilles Fortress, located in the middle Susa Valley, ~~represents a building where~~ all these stones were used. In particular, the walls consist of blocks of strongly schistose and easily splittable rock types. In particular, the Gneiss di Villar Focchiardo was employed for embrasures that overlook the western side, whereas the Gneiss di Borgone and Gneiss di Vaie were used in the masonry and for the fountain of the main parade ground.

Other important gneiss varieties are the jadeite- and phengite-bearing orthogneisses~~orthogneiss~~ that have been exploited in the Sesia -Lanzo Zone as granites~~granite~~ from the economic-commercial point of view (Verde Argento and Verde Selene). The Verde Argento (Fig. 8f) is~~2w) belongs to the Eclogitic Micaschists Complex of the Sesia Lanzo Zone,~~ characterised by a regional metamorphism of high pressure and low temperature. The first evidence of the use of Verde Argento dates back to the 18th century: the rock was used, for example, as an external covering and in the plinths in the nearby church~~Church~~ of the Madonna del Rosario and of the Santi Maurizio and Germano in Borgofranco d'Ivrea (Torino).~~.~~ At the end of the 19th century, the rock was used extensively in the construction of the railway stations connecting Chivasso and Aosta, and in particular in the structure of the railway underpasses in the line between Ivrea and Pont-Saint-Martin (Aosta).~~.~~ Other historical uses are also attested in the Court Building of Ivrea and in other cities for buildings, churches, cemeteries, sidewalks and vineyard supports in the municipalities of Borgofranco, Tavagnasco and Settimo Vittone. Starting from 1975 the quarry became the property of the Vuillermin Company, which has marketed the Verde Argento all over the world; reference examples are the façade of the Presidential Palace in Malé, capital of the Republic of Maldives, and the internal covering of the Singapore subway. Even in Italy, in the area between Piemonte and Aosta Valley, the Verde Argento has been used for the construction of public and private buildings, as well as for restoration and adornment works of the Agliè Castle and the Bard Fortress (Vuillermin 2023).

Finally, the Verde Oropa must be mentioned. This is a heterogeneous gneiss of the Sesia Lanzo Zone in which leucocratic domains alternate with melanocratic ones: the latter are green in colour and partially preserve eclogitic paragenesis. From a macroscopic point of view, it is possible to recognise~~The main constituents are~~ quartz, mica, pyroxene~~phengite,~~

~~omphacite~~, garnet and epidote~~. while titanite, apatite and zircon are present in accessory quantities (Sandrone et al 2004).~~ This stone was quarried close to the Oropa Sanctuary (Biella), where it was widely used for the cloister columns and for the external cladding of the walls.

3.3.3 Serpentinite and metabasites~~Mafic/ultramafic rocks~~

Quarries of serpentinite~~mafic~~ and metabasites~~ultramafic rocks~~ are particularly concentrated in the upper Susa Valley sector, where the rocks of the Liguria-Piemonte Oceanic Units~~main oceanic units~~ occur. These rocks, although easy to work, have been used less than marble and limestone, also because the outcrops are not extensive and continuous and therefore the rocks are difficult to extract. The Verde Susa and the Verde Alpi Cesana (Fig. 8g) represent the ~~varieties~~ most used varieties in the 19th and 20th centuries, for example in the urban passages of Torino (Fiora and Di Pierro 1998). Macroscopically, the rock is typified by the pervasive network of carbonate veins~~.: from a petrographic point of view it can be defined as meta-ophicalcite with chlorite, talc, hematite and spinel.~~ While in the lower and middle Susa Valley similar materials were already exploited in ancient times from erratic boulders, in the upper Susa Valley the quarries were opened at the end of the 19th century and the exploitation~~exploitment~~ continued until the mid--1980's.

Serpentinite and metabasites~~Mafic/ultramafic rocks such as serpentinite and prasinite~~ (Prasinite della Val di Susa) were also used in the mediaeval time, for example in the Sacra di San Michele (UNESCO World Heritage Site candidate) for all the external walls and arches (Borghi et al. 2016). The Sacra di San Michele (~~,~~Fig. 7e), standing on top~~the peak~~ of Monte~~Mount~~ Pirchiriano at 962 m a.s.l., near Sant'Ambrogio village, on the southern side of the Susa Valley, was one of the most important fortified monasteries in southern Europe. Because of its strategic position it was an important stronghold of the Via Francigena, one of the most ancient communication routes in Europe. Another important use of metabasites~~mafic metamorphic rocks and the related coverings (calcschists)~~ is represented by the Fenestrelle Fortress, built in the 18th century across the valley bottom of the Chisone Valley, to defend the Savoy kingdom borders (Fiora et al. 2006).

~~Noteworthy is the *Serpentinite del Favaro* (Favaro Serpentinite) (~~**Fig.** 7~~2x),~~ a) Cathedral ~~dark green or purplish fine-grained metamorphic rock, mainly made up of serpentine and characterised by a pervasive planar foliation, in which relics of the original mantle minerals such as pyroxenes and olivine are visible. This rock, quarried in the Biellese area, was used for the columns and entablature of the Ancient Basilica of the Oropa Sanctuary (Fig. 4e).~~

Fig. 4 a) Basilica of Vercelli, in which Andesite del Chiavolino was used for monolithic columns; b) Arc of Augustus at Susa (Roman Age, 9 BC) built with the Foresto and Chianocco marbles; c) Funerary Stele of the Gromaticus carved using the Marmo di Pont Canavese and preserved at the Garda Museum of Ivrea (Torino); d) Santa Maria Assunta bell tower built in Serizzo at Montecrestese, Ossola Valley; e) Façade of the Sacra di San Michele made of serpentinite and metabasites ancient Basilica in the Oropa Sanctuary covered with Serpentinite del Favaro

3.3.4 Other metamorphic rocks

The Quarzite di Barge (Barge Quartzite), called Bargiolina (Fig. 8h), is a micaceous fine-grained quartzite showing a tabular and homogeneous appearance. The quarries are located on the western side of the Monte Bracco (lower Po Valley). The Bargiolina – known and used since the prehistoric age as substituting material for chert-replacing material, and celebrated by Leonardo da Vinci (Cavallo and Dino 2019) – was intensely exploited from the early 20th century. It is a

valuable dimension stone, used as internal and external stone facing, because of its excellent technical properties ~~-~~(Peretti 1938). For example, it was used for~~on~~ the internal floors of the Regional Museum of Natural Sciences in Torino and in several churches in Piemonte (e.g. Basilica di Superga and San Filippo Neri church). The quartzite crops out at ~~altitudes between~~ 1100 to~~and~~ 1200 m a.s.l.~~..~~. Geologically it represents the ~~metamorphic~~ product of the~~in~~ Alpine metamorphism~~age~~ of Permo-Triassic quartz-arenites deposited above the Dora~~–~~ Maira Unit during the post-Variscan marine transgression (Vialon 1966). There are different chromatic varieties of Bargiolina: golden yellow, pale yellow, olive grey, grey and white (Marmorina variety). The main technical characteristic of the Bargiolina is the regular schistosity, due to thin ~~mica~~ phengite mica layers along which the rocks can be splitted into very thin slabs (1-2 cm thick). ~~The quartzitic bodies are both capping and interlayering the gneisses of the Dora Maira Unit, as concordant layers or as asymmetric lenses, suggesting a local structural setting of narrow isoclinal folds.~~

Finally, the Pietra di Piasco (Piasco Stone) is here mentioned; it is represented by~~,~~ a grey schistose metamorphic rock, made of white mica, quartz and feldspars, intensely altered, coming from the~~oceanic~~ calcschists of the Liguria-Piemonte Oceanic Units~~lower *Val Varaita* Unit~~. It was used throughout the 19th century in several Piemonte monuments, such as some columns and portals in Piazza Vittorio~~PiazzaVittorio~~ Veneto in Torino, in the Cathedral of Fossano (Cuneo), and for several local uses in Varaita Valley (Cuneo).

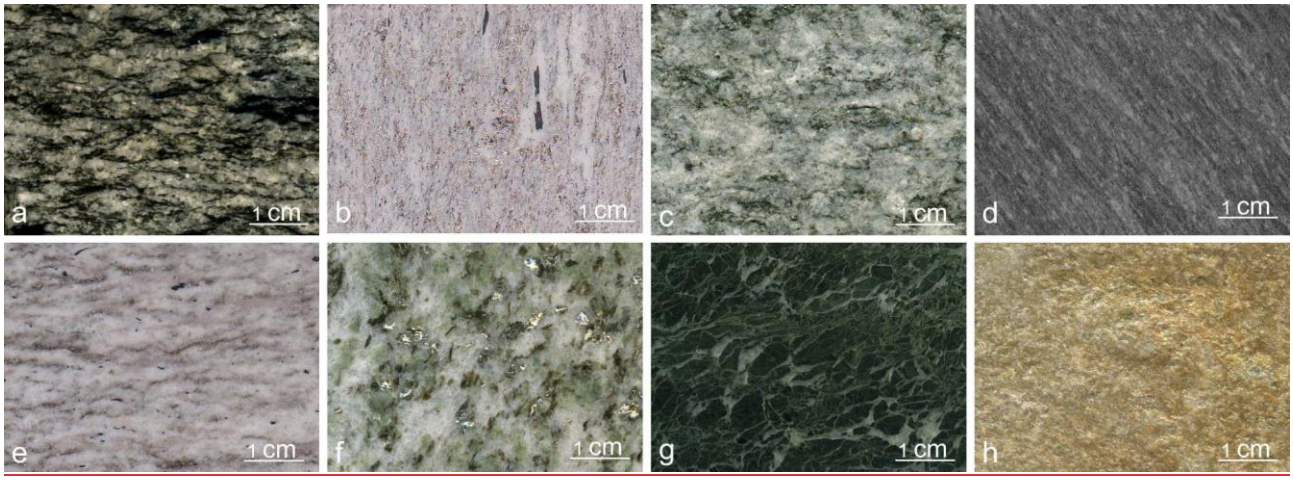


Fig. 8 Example of the most important metamorphic ornamental stones: a) Serizzo Antigorio; b) Beola; c) Pietra di Luserna; d) Pietra di Malanaggio; e) Pietra di San Basilio; f) Verde Argento; g) Verde Alpi Cesana; h) Bargiolina

4. The database~~DataBase~~

The ~~In order to collect and catalogue all the~~ extensive amount of collected data on~~of~~ the ~~considerable~~ historical and cultural heritage regarding~~represented by~~ the stone materials of ~~quarried and used over the centuries in~~ Piemonte has been stored in a DB supporting the Geological Map graphic representation (Fig. 2). A~~, a~~ Data Model was built for the implementation of the DB in order to retrieve the basic geologic information of the GeoPiemonte Map DB (Piana et al. 2017a, b) and to fit it for this thematic purpose. The Data Model was thought to allow linking of the GeoPiemonte Map DB with the new structure of the Ornamental Stone DB. The original Property Classes of the GeoPiemonte Map DB were thus reorganised in order to represent the new instances of the more simple Legend of the Ornamental Stone DB, into the new DB structure. This~~a GeoDataBase. The DataBase~~ was designed to avoid loss of crucial geologic information, as well as to allow describing of new properties such as, for instance, the historical-architectural uses of the stones.

The resulting Ornamental Stone DB, extensively described in Barale et al. (2020) consists of~~using~~ 25 fields (columns) that describe several geological ~~the~~ properties of the stones, as well as their present and historical usages. As the fields of the DB of the WebGIS service are labelled in Italian language, their translations are reported in the following: ~~of the ornamental rocks.~~

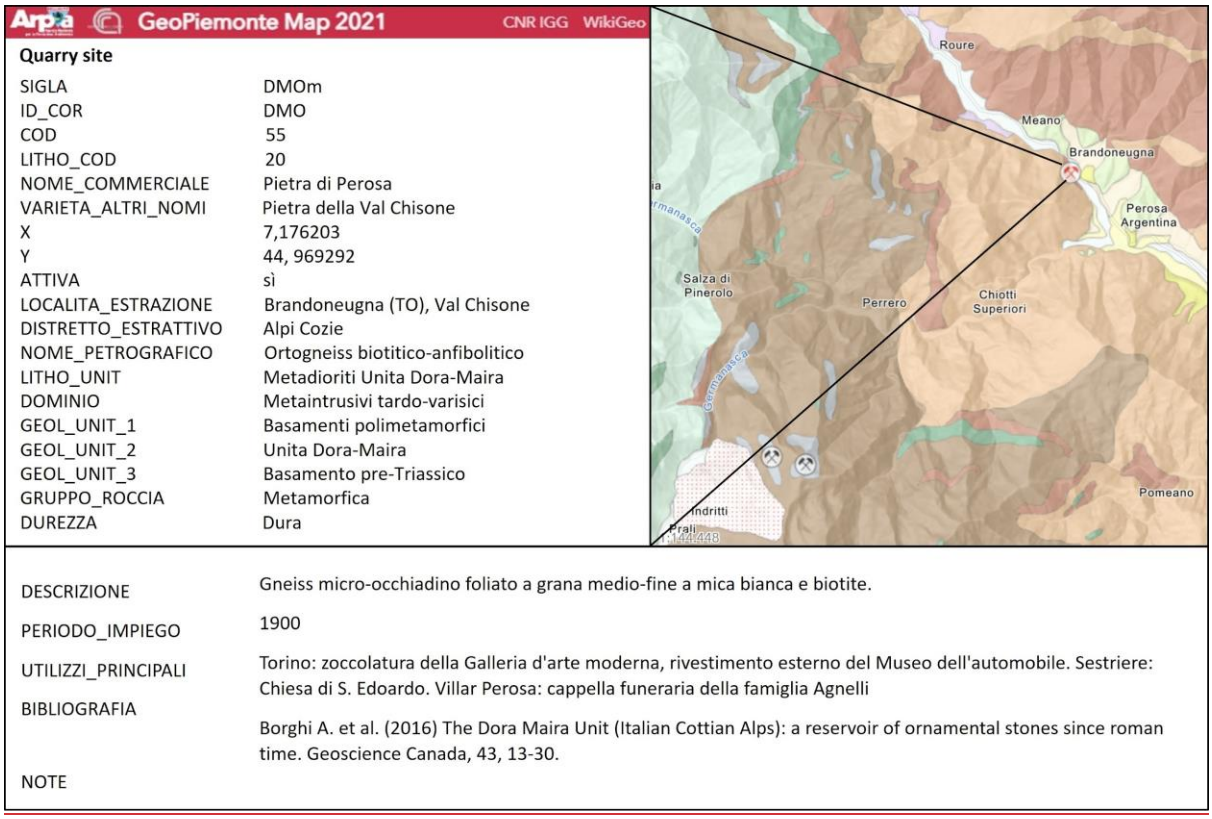
~~The fields present in the Database are reported in the following:~~

SIGLA: identity code; ID_COR: geological unit identification code; COD: ornamental stone identification code; LITHO_CODE: lithology identification code; NOME_COMMERCIALE: commercial name; VARIETA_ALTRI_NOMI: varieties or other name of the ornamental stone; X and Y: geographic coordinates of the quarry; LOCALITA_ESTRAZIONE: locality of extraction; DISTRETTO_ESTRATTIVO: quarry district; ATTIVA: present state of activity of the quarry (yes/no); NOME_PETROGRAFICO: petrographic name of the rock; LITHO_UNIT: geological unit to which the rock belongs; DOMINIO: geological domain to which the rock belongs; GEOL_UNIT_1, 2, 3: higher-ranking geological units to which the rock belongs (as subdivided in the GeoPiemonte Map by Piana et al. 2017a, b); GRUPPO_ROCCIA: rock type; DESCRIZIONE: synthetic lithological description; DUREZZA: hardness of the rock; UTILIZZI_PRINCIPALI: main uses in the architectural field; PERIODO_IMPIEGO: historical age when the stone was mainly used~~period of use~~; BIBLIOGRAFIA 1, 2: main references; NOTE: notes (curiosity, website links etc.) (Fig. 9~~5~~).

5. The Interactive Geolithological Map of ornamental Stones of Piemonte (WebGIS ~~-~~service)

The Geolithological Map of the ornamental Stones of Piemonte (Barale et al. 2020) is now available as a WebGIS service consisting of an interactive map with queryable DB~~DataBase~~: https://webgis.arpa.piemonte.it/agportal/apps/webappviewer/index.html?id=6ea1e38603d6469298333c2efbc76c72.

The map shows the locations of the main quarries in the region, selected on the basis of their cultural, historical and economic significance. The location of the quarries is indicated with a symbol (crossed~~cross~~ hammers), distinguishing the active (red) and inactive (black) quarries~~quarry~~. The symbol has been positioned next to the~~-~~ quarry areas (for active ones) and on the basis of excavation evidence or historical information (for inactive ones). For some lithotypes, occurring~~present~~ in extensive extraction basins with~~, represented by~~ multiple quarries, only the largest or most significant quarries have been reported. Clicking on the symbol of a quarry (e.g. in Fig. 9~~5~~ the Pietra di Perosa quarry), a pop-up window opens showing a series of geological and historical-archaeological detailed information about the extracted ornamental stone.



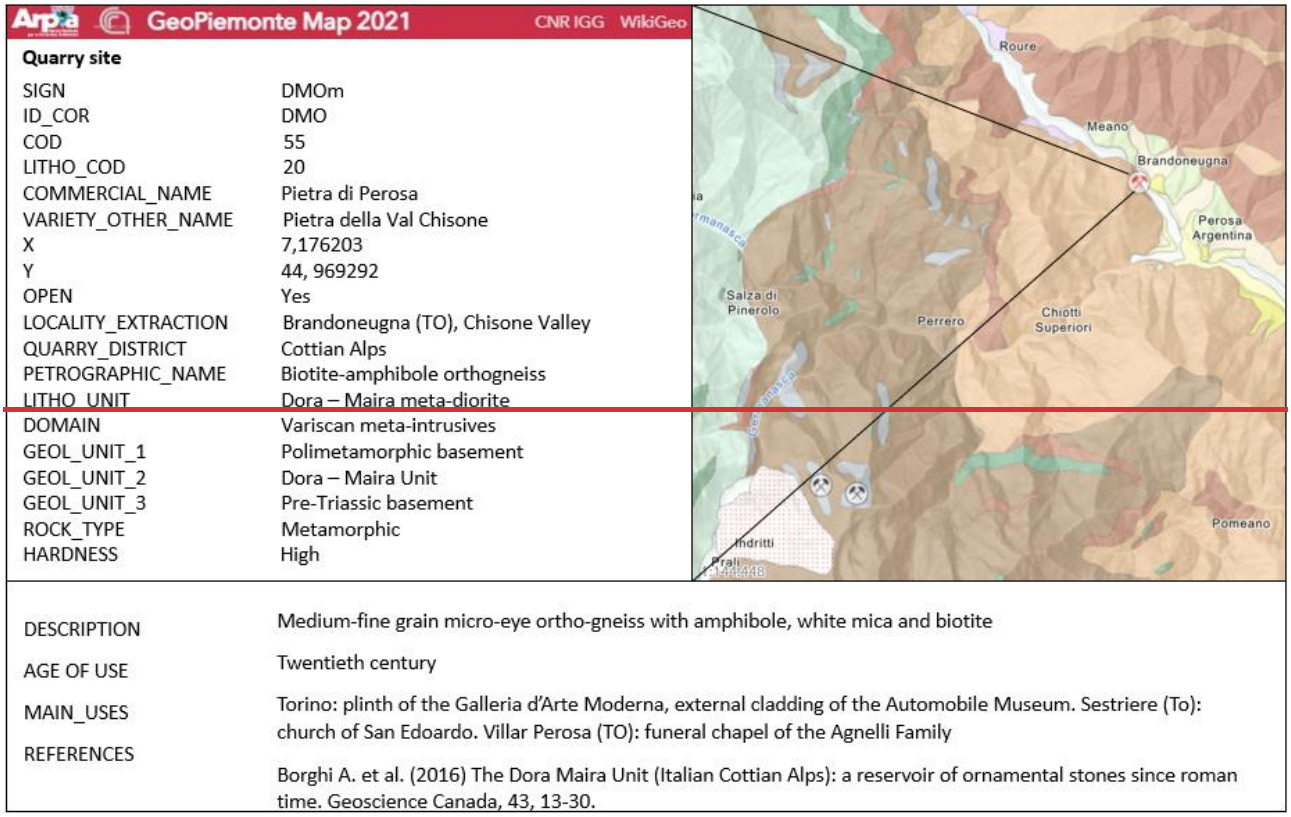


Fig. ~~9~~5 Example of pop-up window and location of the quarry on the GeoPiemonte Map for the Pietra di Perosa

An excerpt from the DB~~database~~ containing the main information on the various ornamental rocks is shown in Table 1 in Supplementary Materials.

On the basis of the list of lithologic varieties and according to their genesis (genetic classes, Fig. 10a), the most abundant ~~rocks are represented by stones essentially consisting of orthogneisses (27%), and mainly distributed in the northern sector of the Verbano Cusio Ossola (serizzi and beole) and Sesia Valleys and in the Cottian Alps (Luserna stone), followed by marbles (25%), mainly present in the Verbano Cusio Ossola area (Candoglia and Creovoladossola marbles) , and in the southern sector of Cuneo province. In smaller quantities there are rocks classified as granites (18%) mainly outcropping in the VCO and Biella provinces. Even less are limestones (14%), concentrated in the Cuneo and Asti Alessandria provinces. Finally, there are mafic and ultramafic rocks (9%) extracted above all in the upper Susa Valley and, in part, in the Ossola Valley, and sandstones (7%) from Cuneo and Alessandria province (Fig. 1 and Fig. 6a).~~

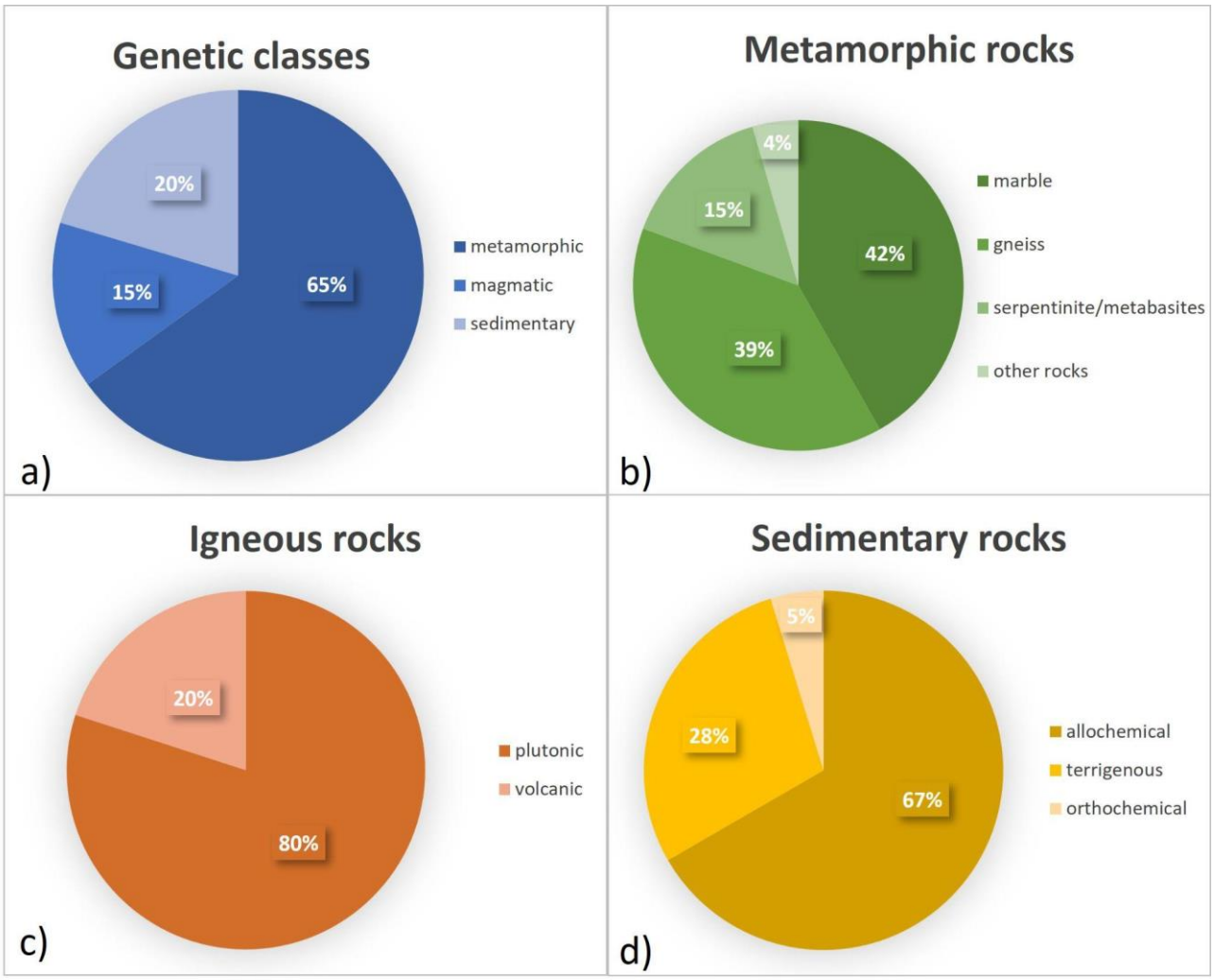
~~If instead the~~ ornamental stones are ~~divided on the basis of their chemical composition, it is possible to see that silicic rocks represent the 45%, followed by carbonate rocks (40%, Fig. 6b). Very small quantities are represented by basic and ultra basic rocks (9%), and siliciclastic sedimentary rocks (6%).~~

~~Regarding their genesis, the prevalent ornamental rocks are obviously~~ metamorphic ones (65%),~~66%), representing the geology of the region,~~ followed by sedimentary~~magmatic~~ rocks equal to 20% ~~and~~ finally magmatic~~sedimentary~~ ones corresponding to only 15 %.

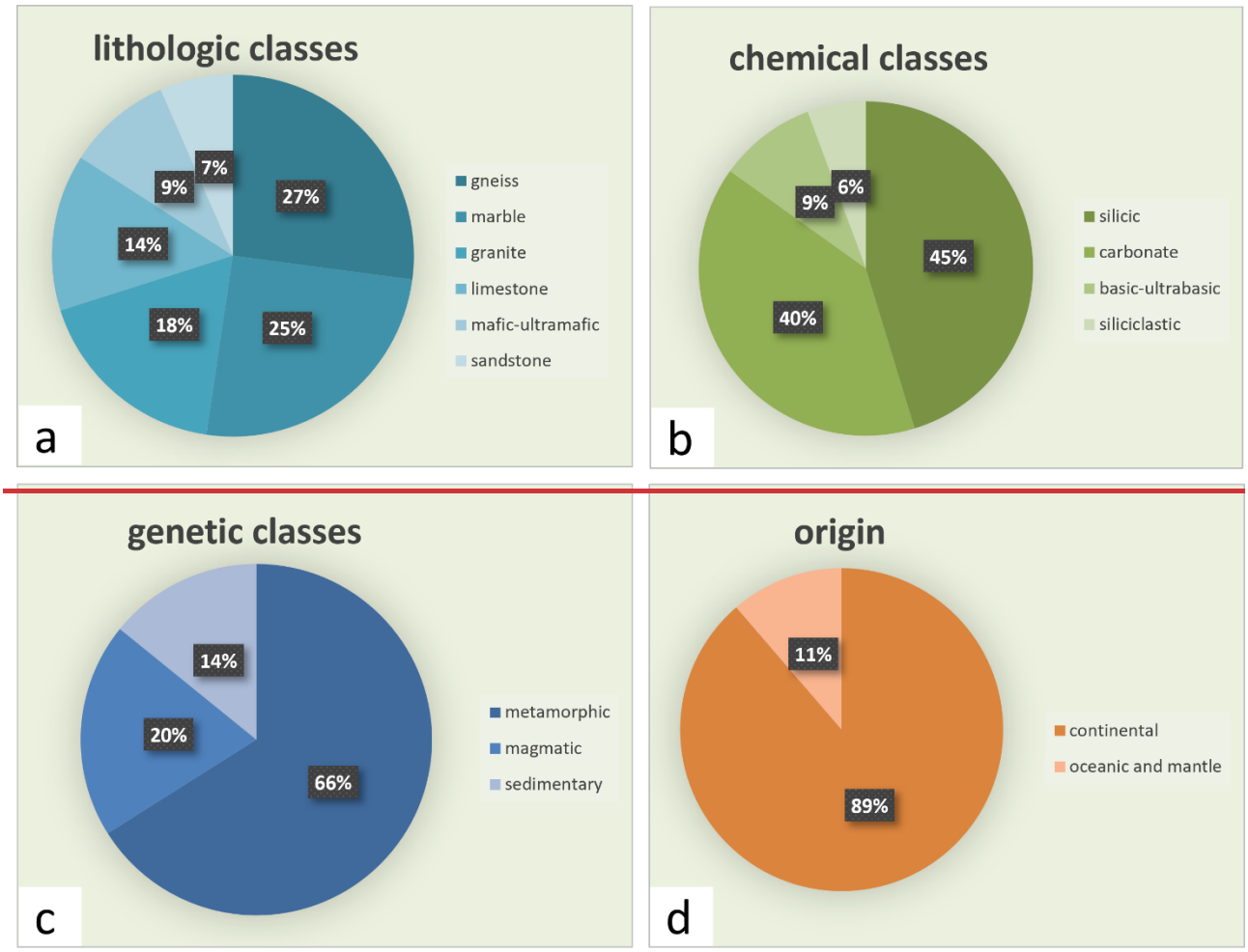
In particular, regarding the metamorphic rocks (Fig. 10b), marbles (42%), mainly present in the VCO area, and in the southern sector of Cuneo province, are followed by gneisses (39%), which are mainly distributed in the northern sector of the VCO (Serizzo and Beola), Sesia Valleys and in the Cottian Alps (Pietra di Luserna); follow the serpentinite and the metabasites (15%) extracted above all in the Susa Valley and, in part, in the Ossola Valley; the other metamorphic rocks, not included in the previous categories, are only the 4%.

Furthermore, it ~~14% (Fig. 6c). It~~ should be noted that igneous rocks (Fig. 10c), mainly cropping out in the VCO and Biella provinces,~~magmatic rocks~~ include both plutonic rocks (80%),~~,~~ present in 16 varieties, and volcanic (20%) ones, quarried in 3 different varieties.

Among ~~Finally, as many as 89% of~~ the sedimentary rocks (Fig.10d), 67%~~extracted~~ are allochemical, concentrated in the Cuneo and Asti-Alessandria provinces, 28% are terrigenous and finally~~of continental origin, while~~ only 5% are orthochemical ~~11% of the~~ rocks.



~~are of oceanic or mantle nature (~~**Fig. 10**~~6d).~~



~~**Fig. 6**~~ Diagrams showing the different subdivisions for the ornamental stones of Piemonte region according to genetic classes (a); the percentage of the rocks, according to their origin, is shown respectively in b) metamorphic, c) igneous and d) sedimentary~~: a) main lithological classes; b) chemical classes; c) genetic classes; d) origin~~

6. Conclusions

The present work~~paper~~ reports the results of~~connected to~~ a research aimed at cataloguing and organising ~~–~~historical ornamental stones of Piemonte region, their lithological descriptions and main uses in the cultural field.

In particular, a census was carried out, followed by the geological characterisation and historical uses for each ornamental stone. In this way, through the DB and the related WebGIS, for the first time, ornamental stones are represented in an organic document based on geological cartography.

This leads to assert that the Piemonte region has been characterised through the centuries by the use of stone in constructions such as religious ~~–~~buildings, of military defence and ~~representation~~ of the main institutional buildings~~institutions~~. However, the stone was also used in the civil sector, particularly in rural buildings in the Alps, as well as, in recent years, for urban furnishings, and in infrastructural works such as bridges, arcades and paving roads.

The characterisation~~characterization~~ of the stones employed is a fundamental step for the enhancement of such valuable material and is addressed not only to geologists, but also to public administrations, industries~~Public Administrations, Industries~~, experts in social sciences and history, experts in cultural heritage, citizens in general, etc. To enhance the

heritage stone of the region, the Interactive Geolithological Map of the ornamental Stonesstones, through a WebGIS service with an associated DBdatabase, was built. In this way, the DB could be a part of a wider tool for natural stones around the world. This tool allows the dissemination of historical and geological information to a wider audience, through appropriate scientific dissemination paths. The Interactive Geolithological Map of the ornamental Stonesstones of Piemonte region is a thematic map, developed from the GeoPiemonte MapGeoPiemonteMap (Piana et al. 2017a), useful for scientific and educational dissemination purposes, to be used by public administrations and geo-sciences professional communities. For each quarry site in the Map, a synthetic description in a WebGISWeb GIS pop-up window is provided.

The interactivity of the map allows a continuous implementation and update of the data. The discovery of new lithological varieties and of unknown historical quarries can be easily reported in the map.

In conclusion, the aim of the Geolithological Map of the ornamental Stonesstones of Piemonte, now available as a WebGIS service, is to raise public awareness about the fundamental role that Earth sciences play in the enhancement of cultural heritage, by the application of the scientific method to the comprehension and conservation of historic buildings and monuments and, in general, for the cultural heritage.

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~~Vuillermin G (2023) http ://www.vuillermin.com/it/granito-verde-argento.html~~

Captions

Fig. 1 Scheme showing the present distribution of the palaeogeographic domains of the Piemonte region (from Piana et al. 2017a, b)

Fig. 21 Simplified lithological map of Piemonte region based on genetic and compositional criteria. The position of the quarries of the ~~Geographic distribution of~~ Piemonte ornamental stones is~~are~~ also reported. The legend at the bottom right indicates active and inactive quarries with different symbols ~~and is according to the ornamental stone classification of Barale et al. (2020)~~

Fig. 3 Macrophotographs~~2 Representative images~~ of the main sedimentary ornamental stones exploited in the past~~quarried~~ in Piemonte region: a) Pietra di Vico; b) Calcare di Gassino; c) Pietra da Cantoni; d) Persichini; e) Nero di Ormea; f) Onice di Busca

Fig. 43 Main examples of employment of Piemonte dimension stones in historic buildings: a) Sanctuary of Vicoforte built in Pietra di Vico; b) ~~colonnade of the pronaos of the~~ Basilica of Superga with several elements in Calcare di Gassino; c) Romanesque church of San Giovanni in Montorfano village built with the Granito di Montorfano; d) Eporedia (ancient Ivrea, Torino province) amphitheatre wall mainly built with Diorite and Gabbro variety of the Granito Nero di Anzola

Fig. 5 Macrophotographs of some magmatic ornamental stones of Piemonte:**4** a) Granito Rosa di Baveno; b) Granito di Montorfano; c) Sienite della Balma; d) Diorite del Canavese; e) Granito Nero di Anzola; f) Granito Rosso Pantheon; g) Pietra del Rongio; h) Andesite del Chiavolino

Fig. 6 Macrophotographs of marbles quarried in the past as ornamental stones: a) Marmo di Foresto; b) Marmo di Pont Canavese; c) Marmo di Candoglia; d) Marmo verzino di Frabosa; e) Marmo Bigio di Moncervetto; f) Marmo Bardiglio di Valdieri

Fig. 7 a) Cathedral~~Basilica~~ of Vercelli, in which Andesite del Chiavolino was used for ~~monolithic~~ columns; b) Arc of Augustus at Susa (Roman Age, 9 BC) built with the Foresto and Chianocco marbles; c) Funerary~~funerary~~ Stele of the Gromaticus carved using the Marmo di Pont Canavese and preserved at the Garda Museum of Ivrea (Torino); d) Santa Maria Assunta bell tower built in Serizzo at Montecrestese, Ossola Valley; e) Façade of the Sacra di San Michele made of serpentinite and metabasites ~~ancient Basilica in the Oropa Sanctuary covered with Serpentinite del Favaro~~

~~Fig.~~ **Fig. 8** Example of the most important metamorphic ornamental stones: a) Serizzo Antigorio; b) Beola; c) Pietra di Luserna; d) Pietra di Malanaggio; e) Pietra di San Basilio; f) Verde Argento; g) Verde Alpi Cesana; h) Bargiolina

Fig. 95 Example of pop-up window and location of the quarry on the GeoPiemonte Map for the Pietra di Perosa

Fig. 106 Diagrams showing the different subdivisions for the ornamental stones of Piemonte region according to ~~: a) main lithological classes; b) chemical classes; c)~~ genetic classes (a); the percentage of the rocks, according to their ~~; d)~~ origin, is shown respectively in b) metamorphic, c) igneous and d) sedimentary

Figure1

Click here to access/download;Figure;Fig.1.jpg

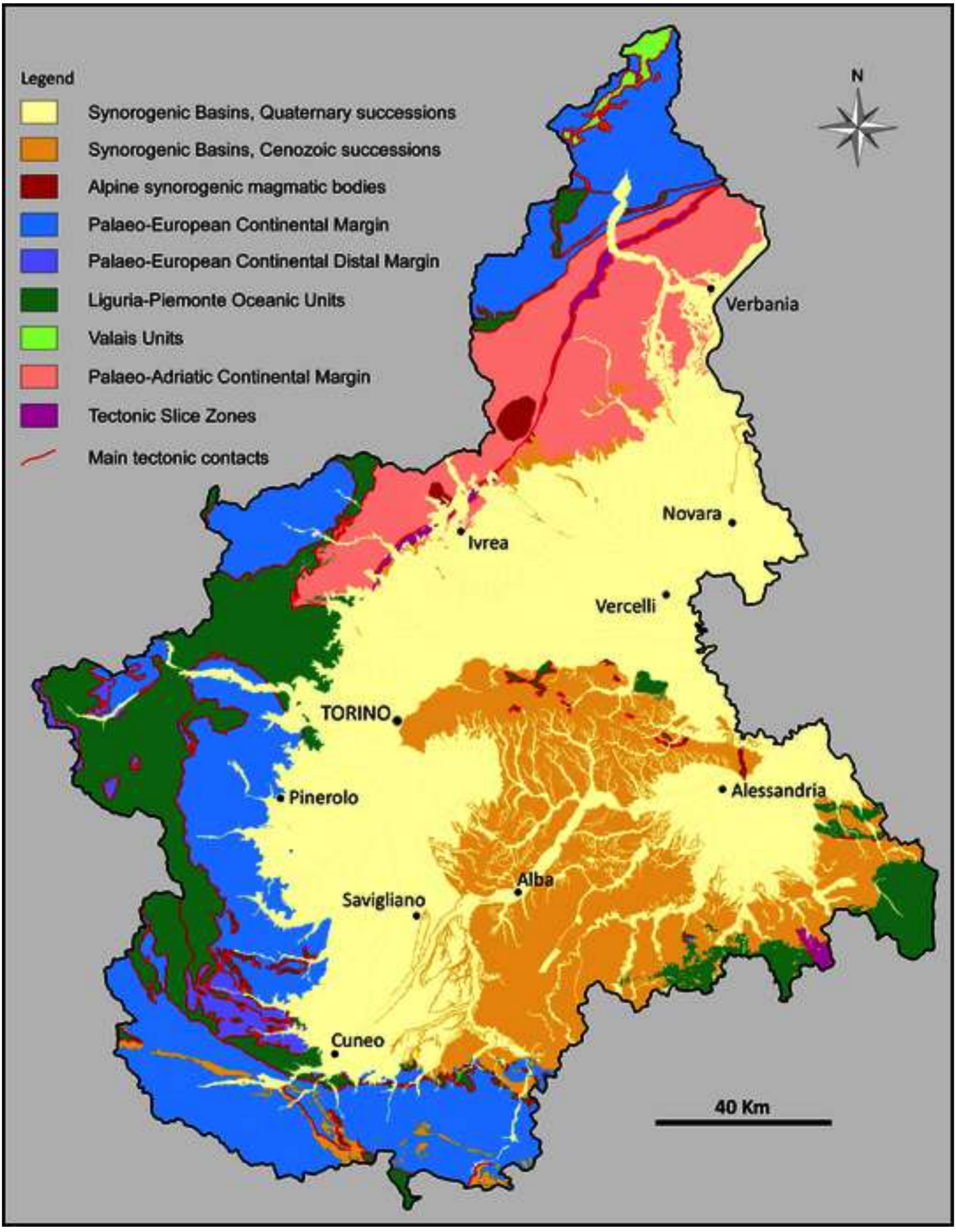

Figure2

Click here to access/download;Figure;Fig.2.jpg

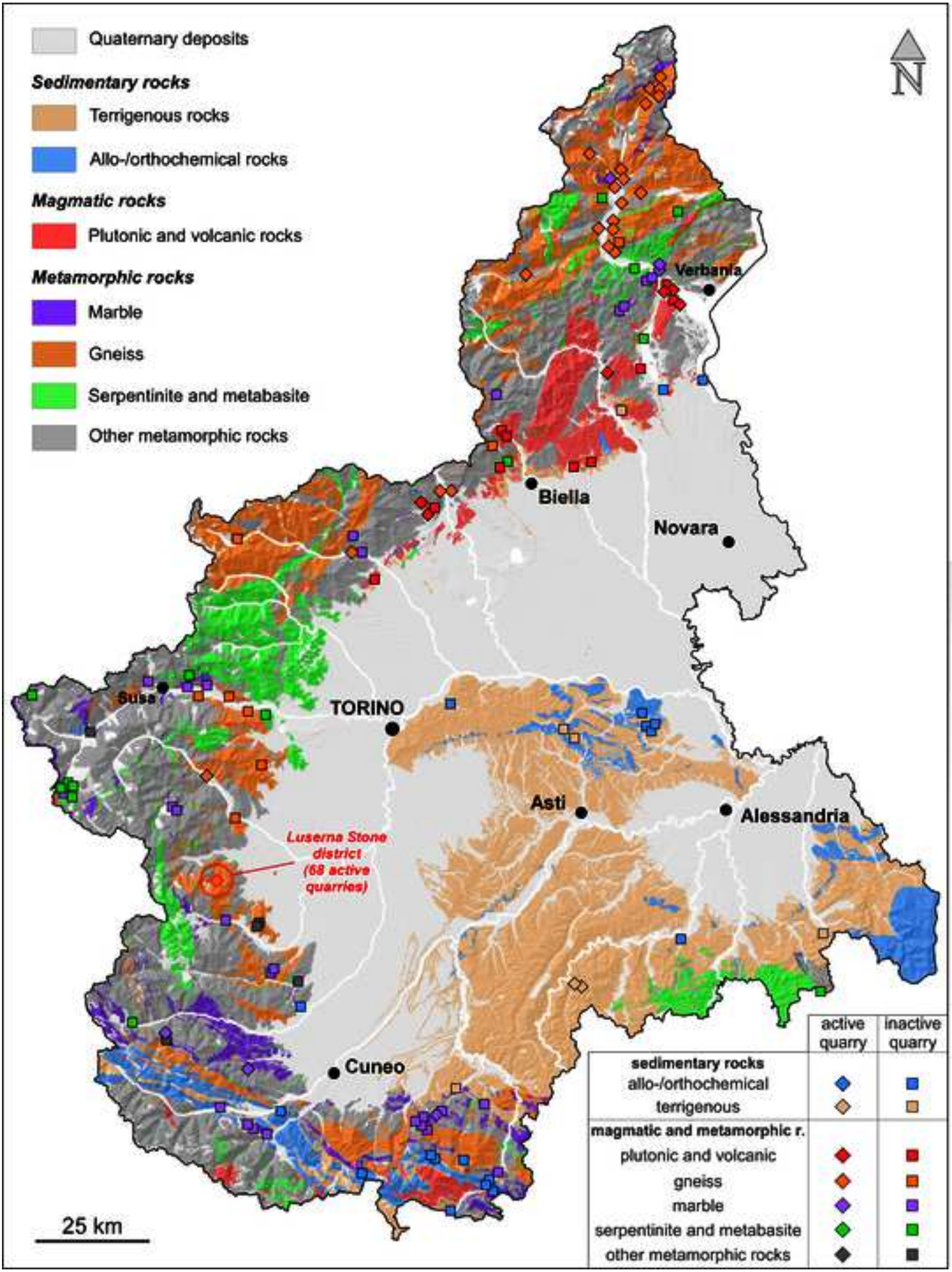

Figure3

Click here to access/download;Figure;Fig.3.jpg

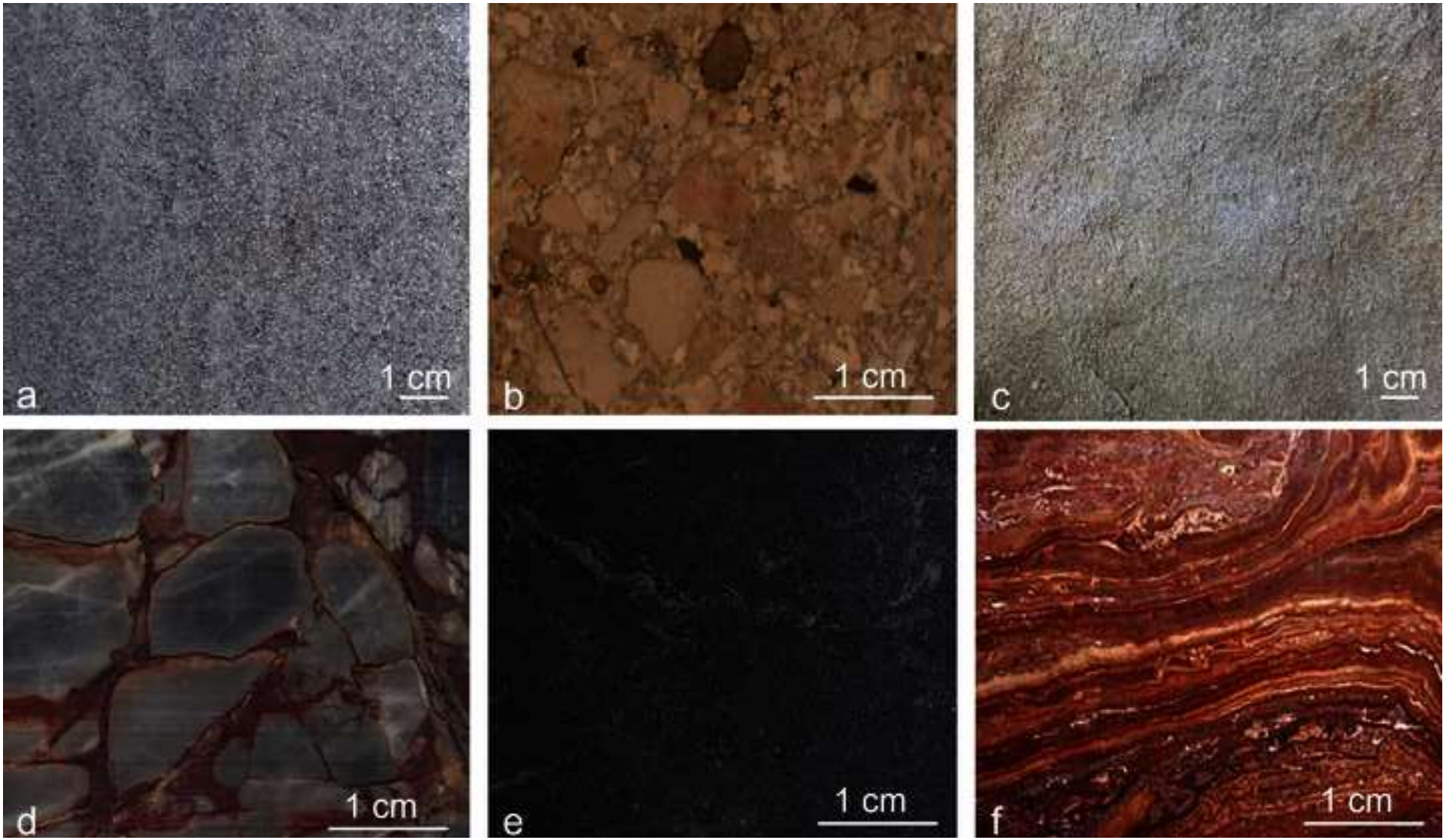

Figure4

Click here to access/download;Figure;Fig.4.jpg

Figure5

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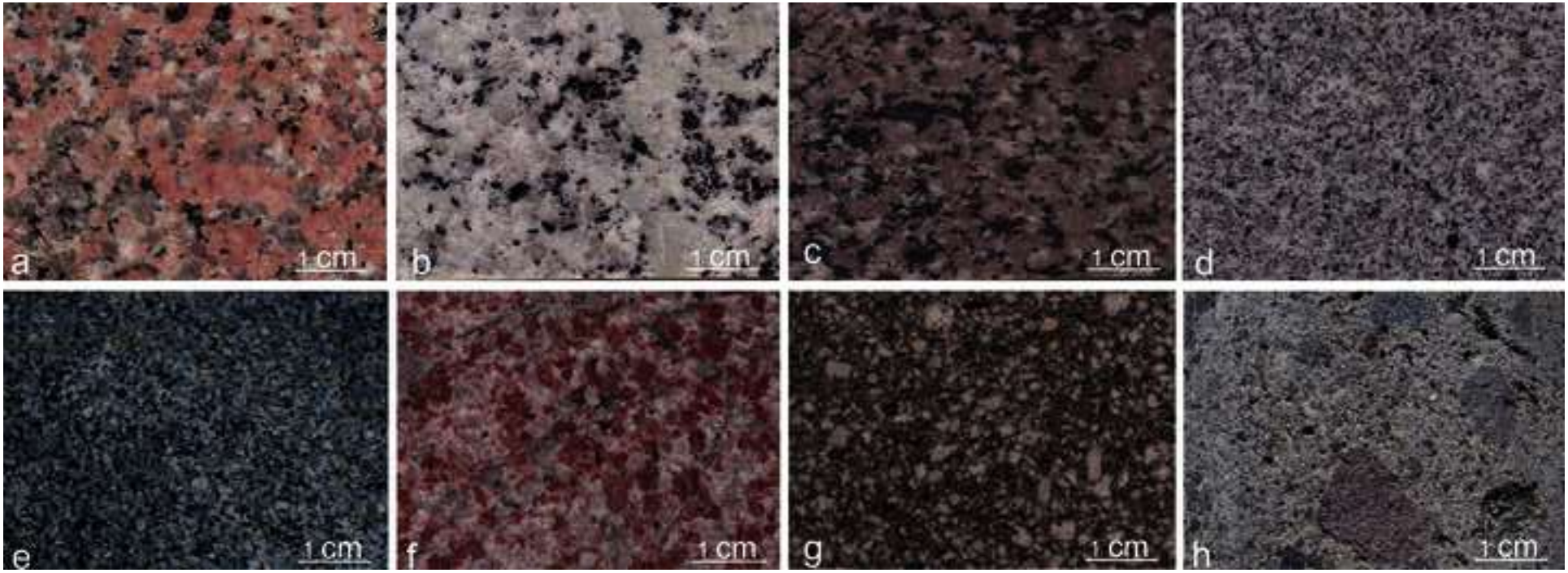

Figure6

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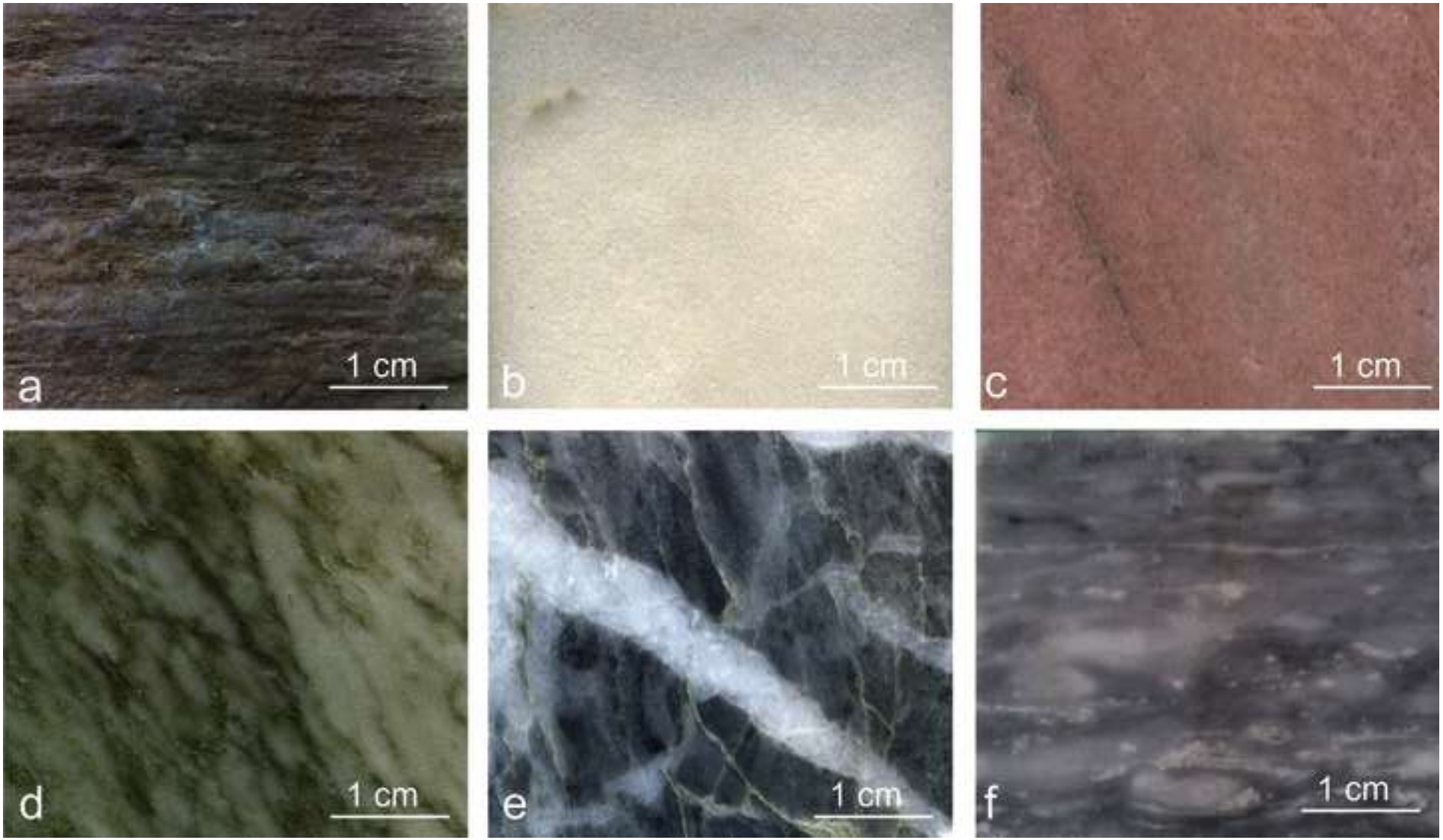

Figure7

Click here to access/download;Figure;Fig.7.jpg

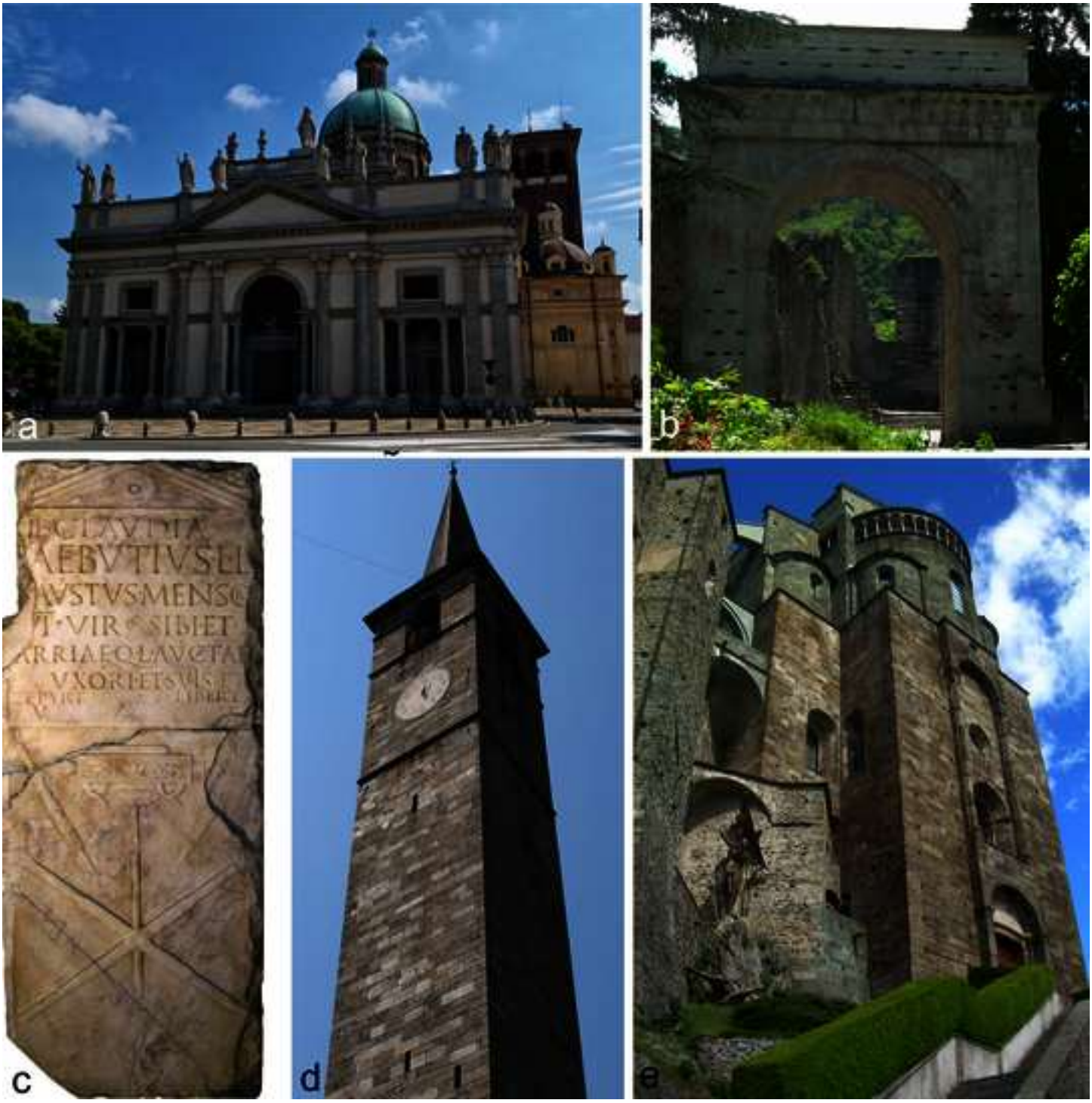

Figure8

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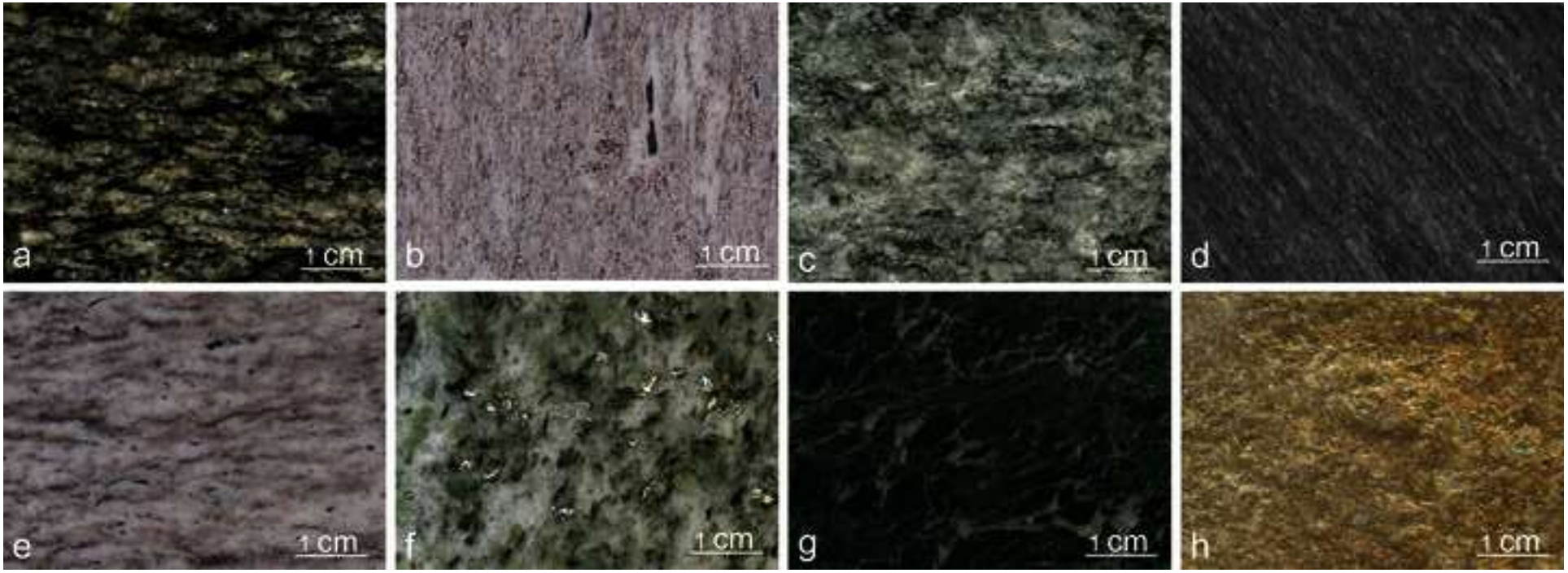
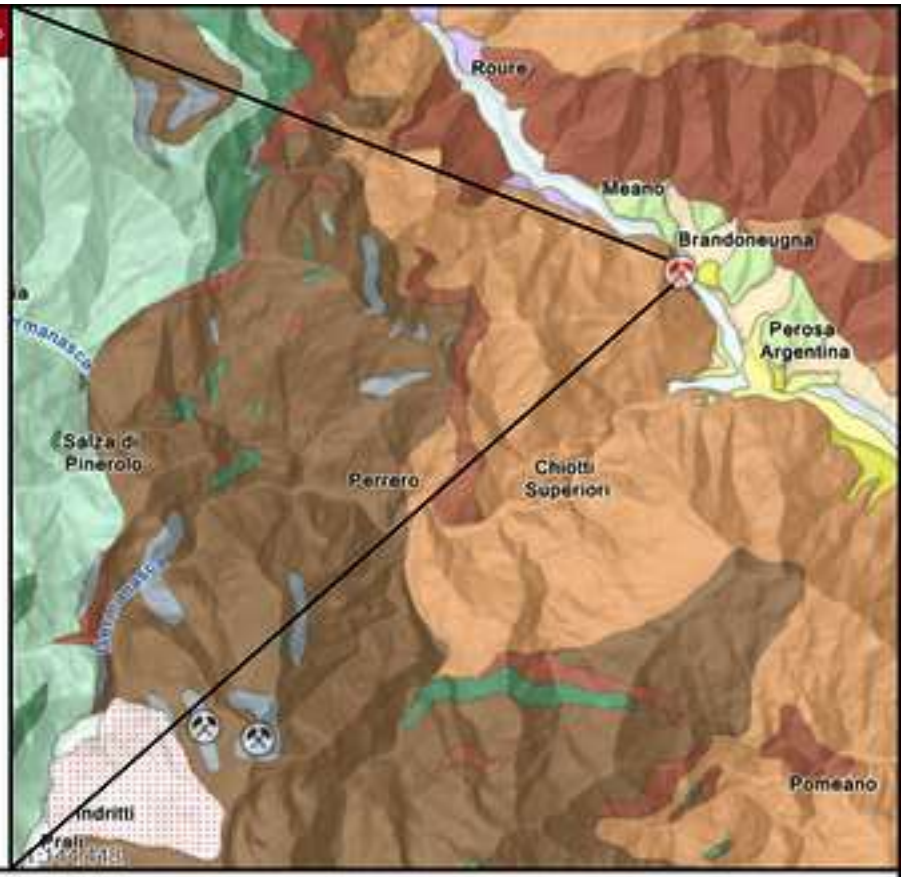


GeoPiemonte Map 2021 CNR IGG WikiGeo

Quarry site

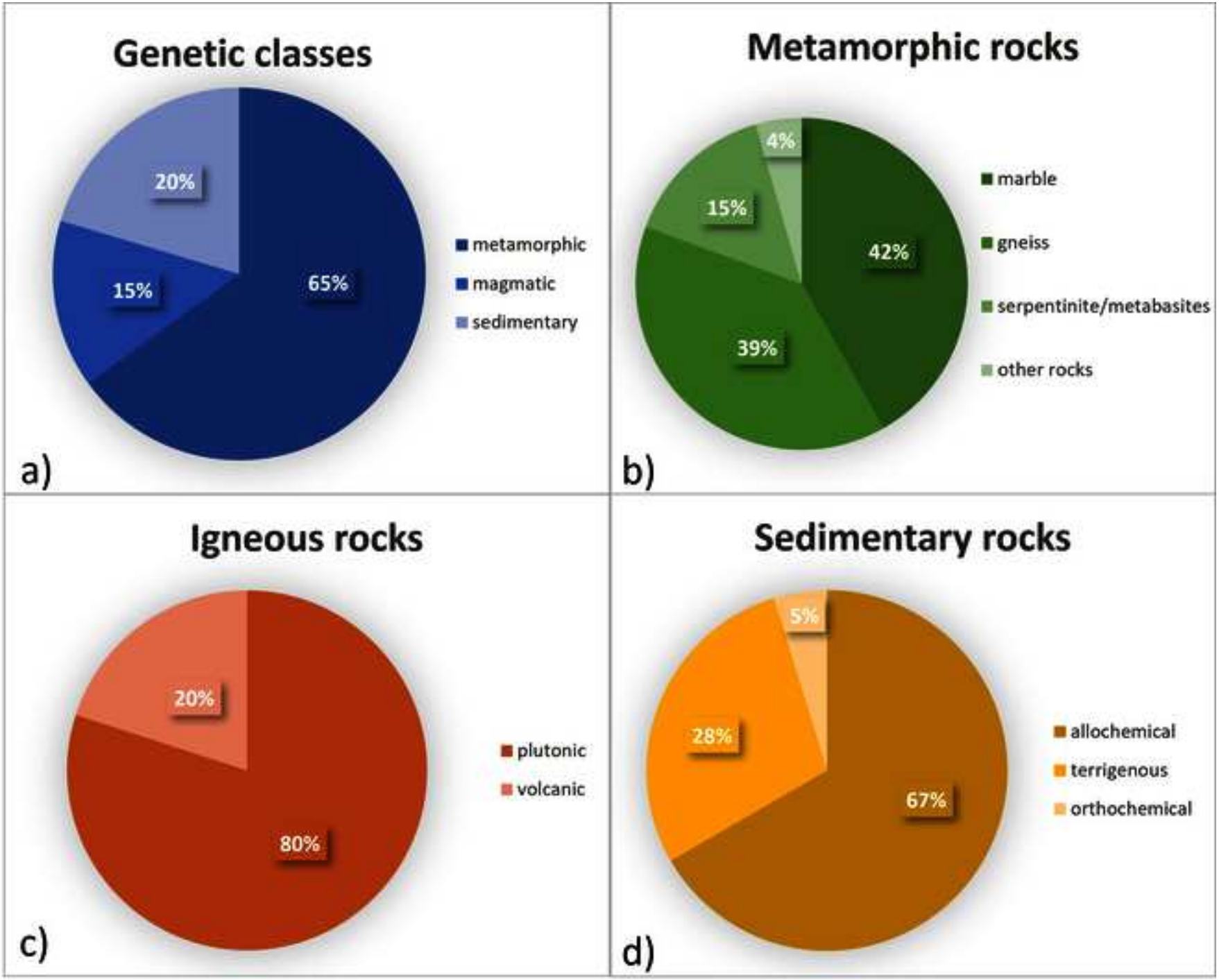
SIGLA	DMOm
ID_COR	DMO
COD	55
LITHO_COD	20
NOME_COMMERCIALE	Pietra di Perosa
VARIETA_ALTRI_NOMI	Pietra della Val Chisone
X	7,176203
Y	44, 969292
ATTIVA	sì
LOCALITA_ESTRAZIONE	Brandoneugna (TO), Val Chisone
DISTRETTO_ESTRATTIVO	Alpi Cozie
NOME_PETROGRAFICO	Ortogneiss biotitico-anfibolitico
LITHO_UNIT	Metadioriti Unita Dora-Maira
DOMINIO	Metaintrusivi tardo-varisici
GEOL_UNIT_1	Basamenti polimetamorfici
GEOL_UNIT_2	Unita Dora-Maira
GEOL_UNIT_3	Basamento pre-Triassico
GRUPPO_ROCCIA	Metamorfica
DUREZZA	Dura



DESCRIZIONE	Gneiss micro-occhiadino foliato a grana medio-fine a mica bianca e biotite.
PERIODO_IMPIEGO	1900
UTILIZZI_PRINCIPALI	Torino: zoccolatura della Galleria d'arte moderna, rivestimento esterno del Museo dell'automobile. Sestriere: Chiesa di S. Edoardo. Villar Perosa: cappella funeraria della famiglia Agnelli
BIBLIOGRAFIA	Borghi A. et al. (2016) The Dora Maira Unit (Italian Cottian Alps): a reservoir of ornamental stones since roman time. Geoscience Canada, 43, 13-30.
NOTE	

Figure10

Click here to access/download;Figure;Fig.10.jpg



Rebuttal letter

The Database of the ornamental stones of Piemonte (NW Italy) hosted in a WebGIS service

by Elena Storta

Dear Editor,

We would like to thank the reviewers for their comments on our submitted manuscript “The DataBase of the ornamental stones of Piemonte (NW Italy) hosted in a WebGIS Service”.

Following their suggestions, we revised our original manuscript making it more robust and convincing.

We responded to all the comments and updated the text accordingly.

The main changes to the manuscript are in agreement with the reviewers suggestions, as recommended.

Below you will find our systematic replies to the reviewer comments.

We hope that you’ll accept this new version of the manuscript for publication.

Kind regards.

Elena Storta,

On behalf of the co-authors

Reviewer #1 comments:

Note: Our comments are in Italic with indentation, in the response to the Reviewer;
the line numbers refer to the first pdf version; we also accepted the suggested changes to the text.

First of all, the manuscript does not conform to the format of the Geoheritage journal. The Geoheritage format must be strictly followed. Please do not just use 'italics' for the expressions in your native language, but an 'in italian' indicating that it is in Italian. No one will know your native language or be able to easily understand your explanations in English.

We changed according to the Journal rules and in agreement with the reviewer.

Abstract

The Abstract is not very adequately prepared to convey the essence of this work. The choice of words and their usage (upper and lower case) is not appropriate. The general usage of this subject should be looked up in the literature. This section should be reorganised.

*Following your suggentions we have partially rewritten the Abstract. As regards upper and lower case of words, the geological map is called "**C**arta **G**eolitologica delle **P**ietre ornamentali del **P**iemonte" (in English Geolithological Map of the ornamental Stones of Piemonte)* with capital letters, *in agreement with CNR-IGG Torino, ARPA Piemonte and University of Torino.*

1. Line 19: This website cannot be reached. Why is an inactive link included? (https://webgis.arpa.piemonte.it/agportal/apps/webappviewer/index.html?id=6ea1e38603d6469298333c2efbc76c72)

We apologize for the inconvenience: There have been problems with the CSI (Consorzio per il Sistema Informativo del Piemonte) directives, in particular, for technical reasons, on the ARPA Piemonte (Co-Authors of the article) server there have been problems in publishing the WebGIS link accompanied by the geological cartography on which the Ornamental Stones Database is based (the problem was that only in certain European countries the link did not work due to security problems). The problem should have been solved and we hope that the link is also visible in your country.

2. Line 23: ...Cultural Heritage... Why this use?

We corrected it.

3. Line 24: The present paper describes... The meaning of a word like ‘paper’ in the manuscript is not appropriate. Here it could be study, work, research and present. Please avoid the use of paper.

We have changed to a more appropriate term.

4. Line 27: The words in the Keywords must also be included in the Abstract.

All the Keywords are included in the abstract. On Line 15 of the introduction we changed stone materials to ornamental stones.

1. Introduction

The main problem with this chapter is that a country like Italy has produced a vast amount of literature on both famous sculpture and natural stone. The Introduction should include some of the thousands of publications from the country that has produced Travertine (Travertine, Allan Pentecost, https://doi.org/10.1007/1-4020-3606-X), such as this Travertine book, and some key references, such as those found in Geoheritage journal. This section is very poorly organised. Basically, the ‘Introduction’ should be divided into three parts.

1. Introduction: Entrance of the basic literature in connection with your topic.

2. Development: Elaboration of the topic ‘ornamental stones’ and ‘WebGIS’ and supporting it with literature.

3. Conclusion: The impact, contribution and difference of the presentation of ‘ornamental stones’ and ‘WebGIS’ topics via ‘DataBase’ should be given.

We have modified the introduction by integrating with further bibliography.

We believe that, since these are Piemonte ornamental stones, it is not necessary to include bibliography that deals with ornamental stones from other Italian regions as Travertine, which was never mentioned in our work. Also following the observations of the Reviewer #2, we have however increased the citations relating to the use of ornamental stones in the field of cultural heritage.

Where abbreviations are given for the first time in this section, you should give the long and clear form.

We corrected it.

1. Line 54: ‘The GeoPiemonte Map was developed by CNR’. What CNR mean here?

We corrected it.

2. The geological diversity of Piemonte

Since the general geological features in this section are based on the main theme of stones; only the map in Fig. 1 is not sufficient. More comprehensive and detailed geological information and a very comprehensive stratigraphic column section of Piemonte should be given.

We have rewritten chapter 2 entirely, with a very detailed geological setting of Piemonte. We have also enriched it with a further figure of a more explanatory geological map. However, we believe that it is not possible to include a stratigraphic column from Piemonte, since the ornamental stones of the region are of both magmatic, sedimentary and metamorphic origin. Furthermore, it is impossible to define a single stratigraphic column for the many and very different sedimentary successions that exist throughout Piemonte, that were deposited in independent basins developed in completely different times and geodynamic contexts (Late Paleozoic to Cretaceous extensional regime, Paleocene-Pliocene compressional one). Rather, a detailed geological framework of the geology of Piemonte has been reported, making reference to the bibliography produced in the last 100 years, integrated with a new geological scheme (Fig. 1) which summarizes and highlights the complex geological evolution.

Line 81: The explanations in Fig. 1 should be checked by a senior geologist. It is also mandatory to mark the N direction on the maps. For Fig.1, you need to get help from a person who is an expert in the subject.

We have modified Fig.1 (now Fig.2) according to your advice, but above all following the comments of reviewer #2. The geological setting is now implemented and integrated with a further figure showing the great paleogeographic complexity of Piemonte (Fig.1).

Line 86-93: The definitions written here cannot be explained in this way. The expressions ‘terrigenous and allo/orthochemical rocks’, ‘plutonic and volcanic rocks’, ‘marbles, gneisses’, ‘mafic/ultramafic rocks’, and ‘other metamorphic rocks’ are very specific. Since you did not define them, you should avoid unattributed descriptions as each topic requires different expertise.

We have integrated the terminology by defining each classification used. We also assume that the geoheritage readers have at least a basic knowledge in Geology; the classification of the rocks we use is at the simplest level of distinguishing great categories according to their genesis (magmatic, sedimentary etc.).

3. Historical Piemonte ornamental stones and their use

The most effective figures and descriptions related to your main theme is a very inadequate point. The rock representation in Fig. 2, the text on the photo and the photo dimensions are not at a level to be published. Separate figures should be produced by separating the rock groups here according to their origins.

For example;

3.1 Sedimentary rocks,

3.2 Magmatic rocks,

3.3 Metamorphic rocks for selected specimens should be grouped separately. Larger scale photographs should be included here.

We have modified according to your advice; now the rocks and their relative figures are separated and reorganized into main groups. The photographs have also been improved and reported in larger dimensions.

In a very important deficiency, the inclusion of thin sections of each rock type in such a study would strengthen the scientific basis of the study and make a significant contribution to the literature. Fig. 2 cannot be defined only with macro samples. There are also features that should be given on thin sections.

For the known ornamental stones, the thin section study has already been done and is the subject of several papers. Furthermore, the thin section study and consequently the minero-petrographic characterization of each rock is the subject of a PhD thesis and will be published in other scientific works. We believe that due to the scope of the work and the purpose of the research, it is not necessary to include a detailed study. Furthermore, the DB does not include the thin section study, only the macroscopic description.

Fig. 3 and Fig. 4 should be given with a more detailed and accurate/professional photography technique. The photography of these art historical buildings should at least be done with a correct perspective. More care should be taken when introducing the most important buildings of your country in an SCI journal.

We have modified it by changing photographs with a more adequate perspective.

Line 96: ...Legend of Fig. 1... writing rules should be observed.

We have modifed.

Line 121-125: ....macrophoraminifera (*Amphistegina, Miogypsina*)... pay attention here, both the fossil genus writing and the description. These benthic foraminifera are the subject of micropaleontology. There is no such term as Macroforaminifera. Smaller or Larger Benthic Foraminifera are used. Correct writing: Larger Benthic Foraminifera (*Amphistegina* and *Miogypsina*) or... *Amphistegina* and *Miogypsina* of LBF genus...

Done.

Line 164: ...early Permian age...The use of 'early' is informal and not a correct expression. For detailed information, please see 'https://stratigraphy.org/chart#latest-version'.

Modified.

Line 351-352: "The main constituents are quartz, phengite, omphacite, garnet and epidote while titanite, apatite and zircon are present in accessory quantities (Sandrone et al. 2004)."

For the rocks in Fig. 2, of which you present macro-samples as well as the reference you cite in this sentence, it is necessary to have thin sections and to identify them.

We have modified, leaving a short macroscopic description.

Line 406-415: This section is meaningless in this way. It should be given as a different concept or additional document.

We do not understand which is the request. This paragraph simply shows which is the structure of DB. In any case, we have rewritten and rephrased this paragraph to make it clearer and more understandable.

5. The Interactive Geolithological Map of ornamental Stones of Piemonte (WebGIS service)

This section should be rewritten. Tables should be made before the figures, including all the propositions you have made for Fig. 5, citing them correctly, giving evidence and uncomplicated expressions. Afterwards, the website flow should be explained with figures. Since you set up the website, your statements remain very closed and cannot be understood.

We have rewritten the chapter to make it more understandable.

The list in Supplementary Material_Table 1 should be included in the text and explained.

We believe that, since they are supplementary materials, it is not necessary to insert the information contained within the section into the text.

Fig. 6 has no meaning without very detailed geological information, including stratigraphic column section and Supplementary Material_Table 1 in the text. The geological literature of the classifications in Fig. 6 should also be consulted.

We have modified the figure making it more understandable; for the reasons stated above we believe that it is not possible to insert a stratigraphic column, nor the information contained in the supplementary material. Fig. 6 (now Fig. 10) has been modified and is in agreement with the countless geological literature regarding the Piedmont region. We believe that Table 1 is best as supplementary materials, also given its size. However, we leave the final decision to the Editor.

As an example;

Fig. 6a. 'mafic-ultramafic?' is not a lithological classification.

Fig. 6b. 'silicic' and 'siliciclastic' are very objectionable. 'Siliciclastic' is a name given to a type of sedimentary rock whose formation is entirely due to mechanical effects.

Fig. 6c. 'volcanic'? Is not your title '3.2.2 Volcanic rocks' related to volcanic rocks?

Fig. 6d. transitional environments? The environments given about the origin are very wrong, some of the rocks you mention in the text cannot form in these two environments.

The figure has been modified and the terms are according to the various classification of rocks and literature, as now explained in Chapter 2.

6. Conclusions

Due to the deficiencies in the above 5 chapters, this conclusion is not appropriate in terms of both subject and scope. Here, my suggestion would be to write the conclusion again after reorganising the previous chapters.

Modified, rephrased and implemented.

Reviewer #2 comments:

Note: Our comments are in Italic with indentation, in the response to the Reviewer; relevant the line numbers refer to the first pdf version; we also accepted the suggested changes to the text.

Dear authors,

Your paper is very interesting and useful. It could serve as a good practice for other natural stones areas. However, before the paper is published, you should correct some minor flaws:

- The paper is focus on heritage. Preservation and use the correct natural stone. However, and because the first part (Introduction) is a sort of review, many previous works should be recognized. Since the creation of the Heritage Stones IUGS working group in 2013, many papers have explained the need of proper characterization of stones, the main and ultimate goal of your paper. You mention in the references Cooper (2015), but before that, and at the same time, other papers sent a call for the need of stone recognition: 10.18814/epiiugs/2013/v36i1/002

Thanks for the useful advice, we have integrated it with the works you recommended and with other bibliography.

- It would be important to mention the international importance of the Piemonte area stones. Many monuments have used some of them. Also, artists used some of those stones during the XIX and XX centuries to build their work and now it is shown in art museums: https://doi.org/10.1007/s12371-017-0265-9

Done.

- Figure 1 is very illustrative. However, the legends you have used should be more helpful in distinguishing the different lithologies. Change the legend of the small square at the bottom right to match the legend of the map (e.g., marble: purple/blue) and explain some vague terms: "stone"???

We modified the legend and followed your instructions. To make the figure easier to read, we decided to unify the two legends, eliminating the commercial classification of the ornamental stones that was present in the legend at the bottom right.

- In Figure 2: Is this your own figure? Did you make the selection? If so, explain in the figure

caption. But also try to select a better representative. For example, serpentinite del Favaro does not look like a serpentinite at all!

Yes, we have made a selection of the main ornamental stones of Piedmont, but as recommended by reviewer #1 We have separated the photographs according to the subchapters. For simplicity, the Favaro serpentinite has been eliminated in the figure, and also in the text.

- 3.3.3 Mafic/ultramafic rocks. With this caption, one would expect a long list of examples, but the main lithology here is serpentinite. Therefore, move serpentinites to the Metamorphic rocks caption, as serpentinite is a metamorphic rock. Leave the others, may be, for the Other metamorphic rocks, or Other rocks in general.

We have directly changed the title of the chapter to "serpentinite and metabasites" but we have kept this subchapter, because rocks of this type in Piedmont are numerous and widely used as ornamental stones. (see division in fig. 2).

- As this is a good practice, I would add at the end (Conclusions?) that the database could be part of a wider tool for natural stones around the world.

We have integrated the conclusions with your advice.

Finally, your paper is badly written. The English is very poor. To be able of publishing this paper in an international journal you should use professional help to polish the language. Otherwise, congratulations for the great effort.

Done.

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Consent for publication

All authors gave consent for publication on the Geoheritage.
All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by [Elena Storta], [Luca Barale], [Alessandro Borghi], [Anna d'Atri], [Giovanna Antonella Dino], [Francesca Gambino], [Luca Martire], [Luigi Perotti], [Fabrizio Piana], [Aldo Acquarone], [Paolo Sassone], [Massimiliano Senesi], [Luca Mallen], [Michele Morelli], and [Gabriele Nicolò]. The first draft of the manuscript was written by [Elena Storta] and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Authors' contributions

- Conceptualization: [Elena Storta], [Luca Barale], [Alessandro Borghi], [Anna d'Atri] and [Fabrizio Piana];
- data collection: [Elena Storta], [Alessandro Borghi], [Luca Barale], [Anna d'Atri], [Giovanna Antonella Dino], and [Fabrizio Piana];
- data analysis: [Elena Storta], [Alessandro Borghi], [Luca Barale], [Anna d'Atri], [Luca Martire] and [Fabrizio Piana];
- writing original draft: [Elena Storta], [Alessandro Borghi], [Luca Barale], [Anna d'Atri], [Giovanna Antonella Dino] and [Fabrizio Piana];
- figures draft and editing: [Elena Storta];
- validation: [Elena Storta], [Alessandro Borghi], [Luca Barale], [Anna d'Atri], [Giovanna Antonella Dino], [Francesca Gambino], [Luca Martire], [Fabrizio Piana], [Luigi Perotti], [Aldo Acquarone], [Paolo Sassone], [Massimiliano Senesi], [Luca Mallen], [Michele Morelli] and [Gabriele Nicolò];
- writing, review and editing: [Elena Storta], [Alessandro Borghi], [Luca Barale], [Anna d'Atri], [Giovanna Antonella Dino] and [Fabrizio Piana].

All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

UNIVERSITY OF TURIN
EARTH SCIENCES DEPARTMENT

Dear Editor-in-Chief,

Enclosed herewith is a manuscript titled, **"The DataBase of the ornamental stones of Piemonte (NW Italy) hosted on a WebGIS service"** for publication **GEOHERITAGE-Sustainability and Heritage in Natural Stone industry.**

The manuscript prepared by Elena Storta, Luca Barale, Alessandro Borghi, Anna d'Atri, Giovanna Antonella Dino, Francesca Gambino, Luca Martire, Luigi Perotti, Fabrizio Piana, Aldo Acquarone, Paolo Sassone, Massimiliano Senesi, Luca Mallen, Michele Morelli and Gabriele Nicolò, has not been published elsewhere.

In this paper a new way to enhance ornamental stones is presented. We believe these findings will be of interest to the reads of your journal.

We well know that **GEOHERITAGE-Sustainability and Heritage in Natural Stone industry** has an important role in the studies regarding topics such as ornamental stones and cultural heritage. For this reason, we sincerely appreciate your time and consideration of our manuscript.

We declare that this manuscript is original, and has not been published before. We confirm that neither the manuscript nor any parts of its content are currently under consideration or published in another journal. All authors have approved the manuscript and agree with its submission to *Geoheritage*.

Sincerely

All authors

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Title: The Database of the ornamental stones of Piemonte (NW Italy) hosted on a WebGIS service

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