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Ornamental stones of Piemonte (NW Italy): an updated geo-lithological map

Luca Barale [a], Alessandro Borghi [b], Anna d'Atri [a,b], Francesca Gambino [b] and Fabrizio Piana [a]

[a]CNR, Institute of Geosciences and Earth Resources, Torino Unit, Torino, Italy; [b]Department of Earth Sciences, University of Torino, Torino, Italy

ABSTRACT
The 'Ornamental Stones of Piemonte Region' geo-lithological map at 1:250,000 scale aims at reviewing the ornamental stone heritage of Piemonte at the regional scale. The map derives from a thorough revision of the available literature, integrated with some unpublished original data. The map shows the location of the main quarries of ornamental stones of the region, selected on the basis of their historical, cultural and architectonic relevance. A geo-lithological basemap was produced, deriving it from a basic Geological Map of Piemonte, available at the same scale. The large varieties of lithotypes of Piemonte have been resumed, in the new map, into 21 classes, which all the ornamental stones have been assigned to. The Main Map is enriched by some significant examples of using the ornamental stones in historical buildings, and it is supported by a supplementary data base containing essential information about the quarry sites and the quarried material.

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Geological map; Lithology; Ornamental stones; Quarries; Western Alps; Piemonte

1. Introduction

In Piemonte region (NW Italy) over one hundred varieties of rocks have been quarried over the centuries as both building and ornamental stones. Quarrying activity is attested since Roman times (e.g. Barelli, 1835; Borghi et al., 2016) and had a progressive development starting from the 16th century under the push of the expanding Savoy Kingdom (Borghi et al., 2014). At present, ornamental stone quarrying is still an important economic activity in the north-eastern part of the region (Verbano-Cusio-Ossola-Sesia Valley district; Cavallo et al., 2019; Dino & Cavallo, 2014), whereas elsewhere it underwent a progressive decay during the 20th century (with a few exceptions, as the Luserna Stone district in the Cottian Alps; Barisone et al., 1979; Sandrone et al., 2004).

The great variety of ornamental and building stones of Piemonte (e.g. Catella, 1969) is due to the extreme geological diversity of the region, which encompasses rock types pertaining to very different geological contexts (Piana, Barale, et al., 2017; Piana, Fioraso, et al., 2017). This complexity is the result of a continuous geodynamic evolution that started since the beginning of Mesozoic leading to the individuation, in the Paleozoic Pangea supercontinent, of two continental passive margins: the palaeo-European and palaeo-Adriatic margins, separated by the Alpine Tethys oceanic domain. Since Late Cretaceous, the convergence of the two continental margins induced the subduction of the interposed oceanic lithosphere, followed by the collision and mutual indentation of the two plate margins (e.g. Dal Piaz et al., 2003; Dewey et al., 1973; Handy et al., 2010). In this frame, the Alps-Apennines orogenic system originated, involving continental and oceanic crustal units that were affected by a multistage metamorphic and tectonic reworking. Since middle Eocene, synorogenic sedimentary basins developed in front of the Alps-Apennines orogens and became themselves progressively involved in the overall tectonic system (Piana, Barale, et al., 2017; Piana, Fioraso, et al., 2017).

A concise graphic representation on a map of such a complex geology and geodiversity, requires the setting up of some classification criteria suitable for the task at hand. For our purposes, these criteria should be well-suited for both the readers not too skilled in geology, as well as the experts in the area. The proposed map is thus a simplified lithological map, consisting of 21 lithological classes, showing the distribution of the ornamental stones exploited in Piemonte. It was obtained by modifying the basic Geological Map of Piemonte (GeoPiemonteMap, Piana, Fioraso, et al., 2017) and its Data Model, also available as a WebGIS service (https://webgis.arpa.piemonte.it/Geoviewer2D/index.html?config=other-configs/geologia250k_config.json).

The Main Map reports the location of the selected active and inactive ornamental stone quarries, which have been subdivided into five 'quarry districts' on the basis of geographic and historic criteria (Figure 1).

CONTACT Francesca Gambino francesca.gambino@unito.it Department of Earth Sciences, University of Torino, Via Valperga Caluso 35, Torino, Italy

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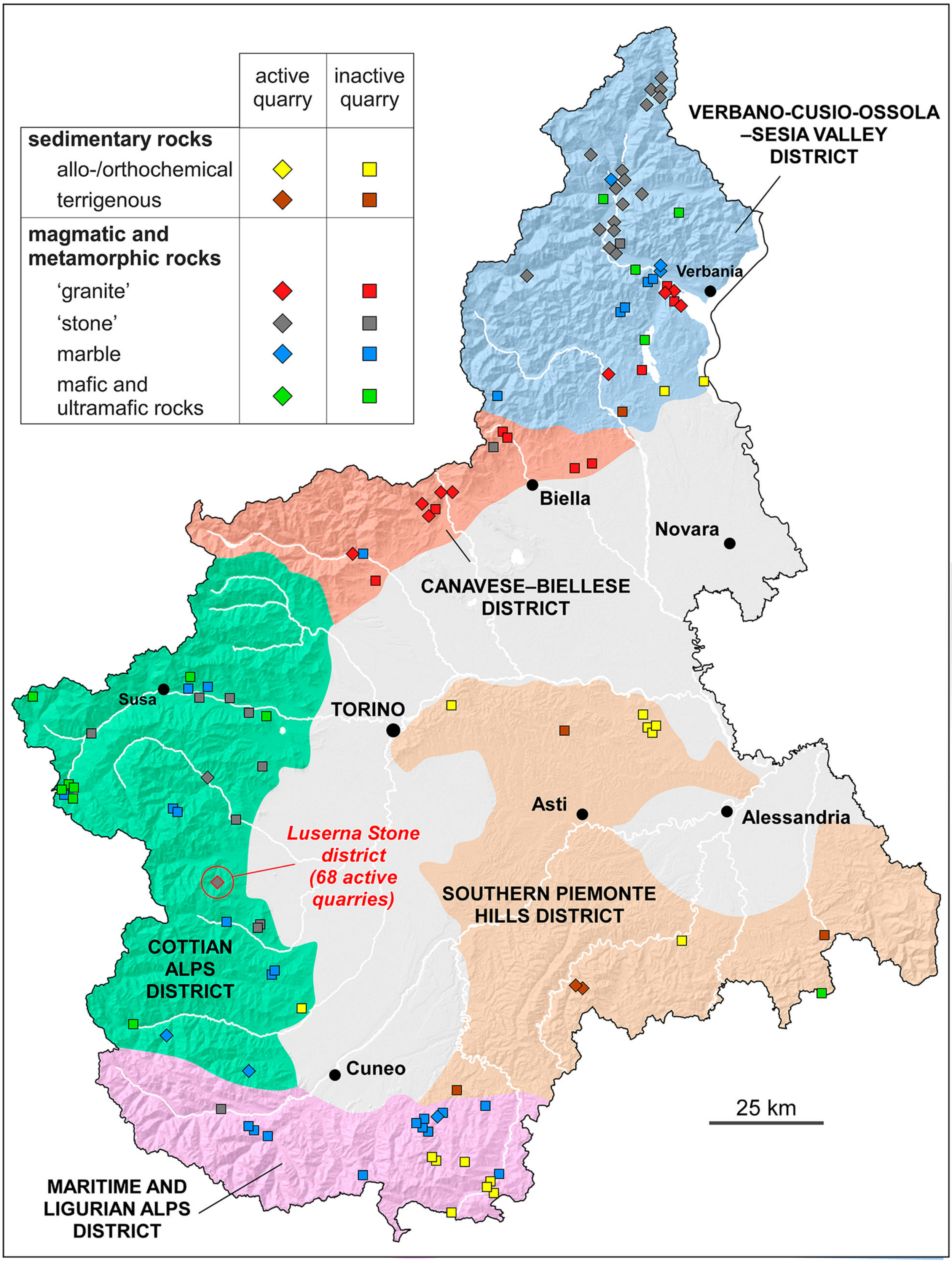

Figure 1. Scheme of the quarry districts of Piemonte.

The basic information about the quarry site and the quarried material is reported in a database (Supplementary Material 1). Six representative historical buildings have been reported on the Map as ancillary graphics to provide an overview of the final use of some ornamental stones quarried in Piemonte (see section 4).

2. Map representation criteria

The complex legend of the basic GeoPiemonteMap (Piana, Barale, et al., 2017; Piana, Fioraso, et al., 2017), which includes more than two hundreds items representing the complex geological setting of the region, has been simplified here, using strictly lithological criteria. In this way, only 21 synthetic lithological units were created for the pre-Quaternary rocks of the region, each grouping rocks characterised by homogeneous lithology, even if belonging to geological units characterised by different paleogeographic origin, geological evolution and age. The Quaternary deposits, not crucial for the description of the ornamental stones, but essential for a complete cartographic representation, have been grouped into other four classes.

2.1. Map legend

The 21 lithological units of substrate rocks have been grouped into *Sedimentary Rocks*, *Magmatic Rocks*, *Metamorphic Rocks* and *Fault Rocks*. Quaternary deposits have been subdivided into four units (*Recent alluvial deposits; Terraced alluvial deposits; Glacial deposits; Landslide, block stream and rock glacier deposits*) which are not further described here since they have no relevance for ornamental stone quarrying. A short description of the rock types included in each lithological unit is given in the following, with essential bibliographic references (for an extended regional bibliography, the reader is referred to Piana, Barale, et al., 2017). For each lithological unit, the main ornamental stones (e.g. those reported in Figure 2) are also listed.

2.1.1. Sedimentary rocks

Subdivided into five units according to their origin (terrigenous, allochemical, and orthochemical) and age (Mesozoic or Cenozoic).

- *Cenozoic terrigenous rocks (tec):* arenaceous, arenaceous – pelitic, marly and sandy – gravelly successions of middle Eocene – Miocene age (Tertiary Piemonte Basin, BTP); upper Eocene-lower Oligocene arenaceous-pelitic successions (Alpine Foreland Basin); pelitic and arenaceous Pliocene successions; conglomerate and chaotic pebbly mudstone successions (Ligurian units of Monferrato). Cemented arenites and greywackes of the BTP succession were exploited as dimensional stones in the past (*Vico Stone*; *Villadeati Stone*; *Montaldero Stone*) and are locally still exploited (*Langa Stone*).
- *Mesozoic terrigenous rocks (tem):* Lower Triassic quartzarenite, Upper Triassic pelite (Provençal Dauphinois External Briançonnais successions); varicoloured argillite, pelite and arenite (Ligurian units of Maritime Alps; Ligurian units of Northern Apennines). Mesozoic terrigenous rocks were only rarely exploited for local uses (*Monte Fenera Sandstone*, an Early Jurassic lithic greywacke from the mainly carbonate succession of the Southalpine Domain).
- *Cenozoic allochemical rocks (alc):* Calcarenite and calcirudite of Eocene to Miocene age (BTP; Alpine Foreland Basin); calcareous-marly turbidite successions of Eocene age (Ligurian units of Monferrato). In the BTP succession, the *Gassino Limestone*, a biocalcirudite of Eocene age (Campanino & Ricci, 1991), was used as ornamental stone in Torino in the 18th–19th centuries, largely employed in the Basilica di Superga. Miocene biocalcarenite and biocalcirudite of the BTP were exploited in Monferrato (*Pietra da Cantoni*) and Alto Monferrato sectors (*Visone Stone*).
- *Mesozoic allochemical rocks (alm):* Middle Triassic – Jurassic carbonate and Cretaceous marly limestone successions of the Palaeo-European Continental Margin (Provençal-Dauphinois-External Briançonnais succession), Middle Triassic – Jurassic limestone and dolostone of the Palaeo-Adriatic Continental Margin (Southalpine sedimentary succession), and calcareous-marly turbidite successions of Cretaceous age (Ligurian units of Maritime Alps; Ligurian units of Northern Apennines). Historic ornamental stones were exploited from the Triassic-Jurassic succession of the External Briançonnais Domain (*Persichino di Garessio, Persichino di Corsaglia, Bardiglio di Garessio, Portoro di Nava, Nero di Ormea, Casotto Breccia*), largely used in Torino in the 18th-19th century, and from the Middle Triassic-Lower Jurassic Southalpine sedimentary succession (*Angera Stone, Gozzano Limestone*), mostly for local uses.
- *Orthochemical rocks (ort):* Primary and resedimented Messinian evaporitic gypsum (BTP), main gypsum and anhydrite masses within tectonic contact zones, speleothems. Metre-thick bodies of speleothems (calcite alabaster) filling fissures within the dolomite marble of Dora Maira Unit were exploited in the past as *Busca Onyx*.

2.1.2. Magmatic rocks

Subivided into four classes according to their composition (acid or basic) and emplacement mechanisms (plutonic or volcanic).

- *Acid volcanic rocks (voa):* Permian volcanic and volcaniclastic rocks of the palaeo-European continental margin (Provençal-Dauphinois-External Briançonnais succession) and of the palaeo-Adriatic continental margin (Permian magmatic Complex, Southalpine Domain; Canavese Zone). Several-metre-thick dykes of subvolcanic porphyritic rocks, intruded in Permian volcanites (*Rongio Stone*) and granites (*Ponte Guelpa Stone*) of Biellese area were quarried for local uses.
- *Acid plutonic rocks (pla):* Permian granite (Southalpine Domain, Lake Massif, Cavallo et al., 2004b;

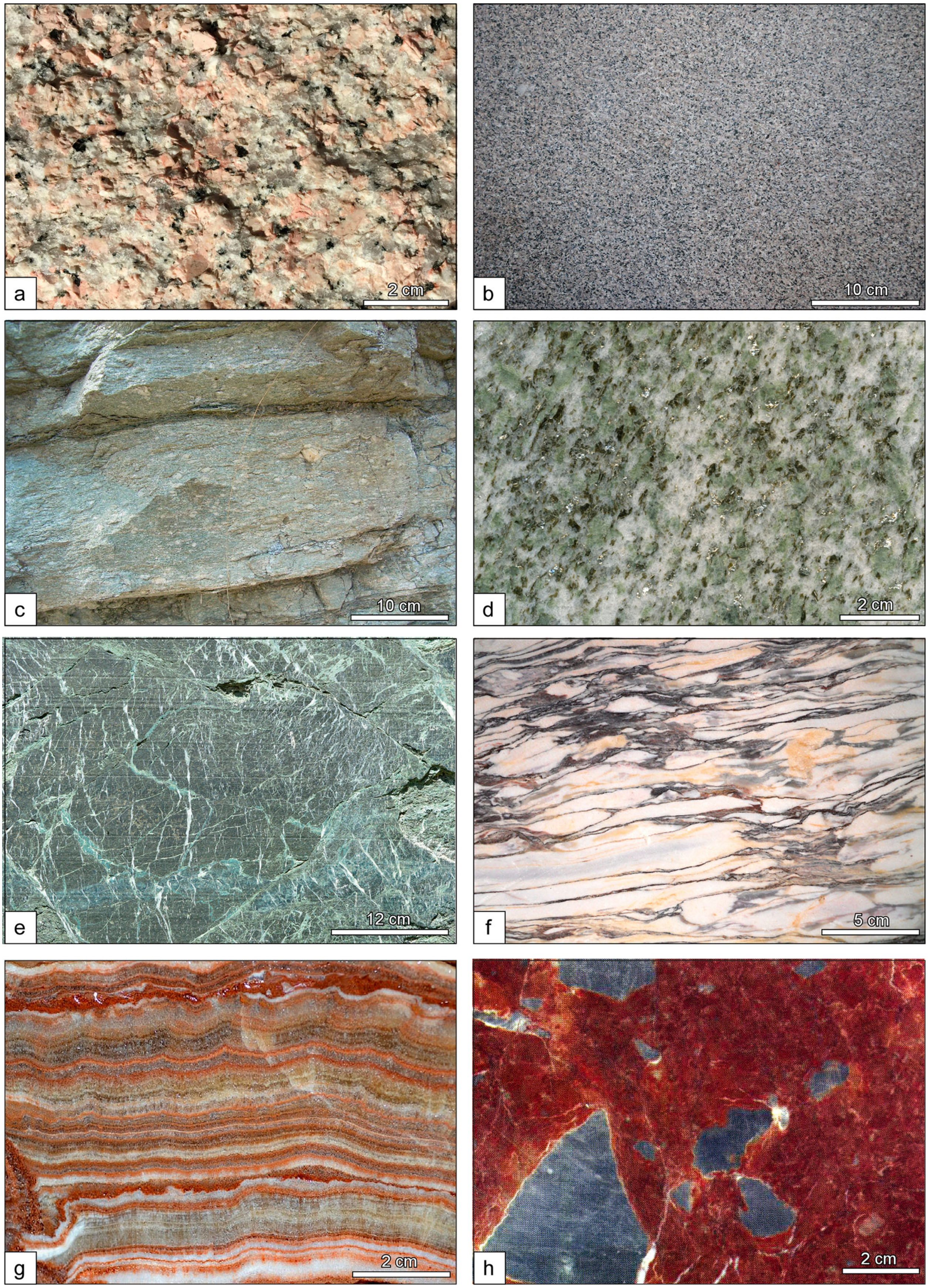

Figure 2. Examples of ornamental stones of Piemonte: (a) *Baveno Granite*, Verbano Cusio Ossola – Sesia Valley district; (b) *Balma Syenite*, Canavese – Biellese district; (c) *Luserna Stone*, Cottian Alps district; (d) *Verde Selene*, Canavese – Biellese district; (e) *Verde Alpi*, Cottian Alps district; (f) *Cipollino di Valdieri*, Maritime and Ligurian Alps district; (g) *Busca Onyx*, Cottian Alps district; (h) *Persichino di Corsaglia*, Maritime and Ligurian Alps district.

Canavese Zone; Argentera Massif). Permian granite of the Southalpine Domain were and still are largely quarried in the Lago Maggiore-lower Sesia Valley sector (*Montorfano, Baveno, Alzo, Quarona granites*). Alpine synorogenic magmatic bodies of Oligocene age (Biella, Traversella, and Miagliano plutons; Alagna et al., 2010; Bigioggero et al., 1994); these provided important building stones (*Vico, Traversella and Brosso Diorite*; *Balma Syenite*), largely used in Torino from 15th to 20th century.

- *Basic volcanic rocks (vob):* Oligocene andesite and basic pyroclastic rocks of the Biella Volcanic Suite (Alpine synorogenic magmatic bodies). Rare bodies of pillow basalt and basalt breccia derived from the Liguria – Piemonte Oceanic Domain which escaped Alpine metamorphism (Chenaillet Unit, Polino, 1984; Figogna Unit of the Sestri – Voltaggio Zone; Cortesogno & Haccard, 1984). No ornamental stones from these lithotypes are reported on the map.
- *Basic plutonic rocks (plb):* masses of gabbro, gabbronorite, amphibole gabbro and diorite to tonalite (Ivrea – Verbano Mafic Complex, IVMC, of Southalpine Domain; Mazzucchelli et al., 2014; Rivalenti et al., 1984). Gabbro and dolerite dykes of the Chenaillet Unit (Liguria – Piemonte Oceanic Domain). The *Anzola Black Granite,* a gabbro-norite of the Ivrea-Verbano Zone, was extensively used for funerary art during twentieth century.

2.1.3. Metamorphic rocks

Subdivided into 11 large classes on a merely lithological basis.

- *Phyllite, slate and calcareous schist (sch):* Early Cretaceous phyllite and slate (Sestri – Voltaggio Zone; Cortesogno & Haccard, 1984). Cretaceous calcareous schist of the Internal Briançonnais Units. No ornamental stones from these lithotypes are reported on the map.
- *Calcschist (cls):* Cretaceous calcschist and calc-micaschist, locally containing bodies of paragneiss, marble, carbonate breccia and ophicarbonate (Liguria – Piemonte Oceanic Domain and Valais Domain; e.g. Deville et al., 1992; Elter, 1971; Lagabrielle et al., 1984; Martin et al., 1994). Alternations of prevailing calcareous schist, quartz-micaschist and phyllite, with carbonate breccia bodies, of Jurassic-Cretaceous age, belonging to the Palaeo-European Continental Distal Margin (Pre-Piemontese Auct.; Caron, 1971). Calcschist were not reported among the ornamental stones on the Main Map because no proper quarries of these rocks existed, though in the past they had a widespread local and rural usage (e.g. roof coverings, drywalls), and were also used in numerous architectural elements of historic buildings in the Cottian Alps (e.g. Fenestrelle Fortress, Sacra di San Michele; see below).
- *Marble (mrb):* marble and dolomitic marble of different age are widespread in many units of Piemonte Alps (Borghi et al., 2009). They mainly consist Triassic-Jurassic marble in the meta-sedimentary units of Alpine Axial Belt (Internal Briançonnais units; Continental Distal Margin; Dora Maira Unit). Marble lenses occur in the crystalline basements of pre-Mesozoic age of the Palaeo-European Continental Margin (Dora Maira Unit) and of the Palaeo-Adriatic Continental Margin (Ivrea Verbano Zone, Southalpine Domain; Sesia-Lanzo Zone, Austroalpine Domain). Marble and silicate-bearing marble of Triassic-Early Jurassic age are present in Liguria-Piemonte Oceanic Domain and Valais Domain.

  Several varieties of these marbles were exploited in the past: Mesozoic marbles from the Internal Briançonnais units of the Monregalese area (e.g. *Bianco di Garessio*, *Nero nuvolato di Miroglio*, *Viola Piemonte*, *Bigio di Moncervetto*, *Seravezza di Moncervetto*, and *Frabosa* marble, with the varieties *Bianco*, *Verzino*, *Giallo*, *Bigio*, *Nero*) and from the Lepontine units (*Crevoladossola Marble*); pre-Mesozoic marbles from Sesia-Lanzo Zone (*Pont Canavese Marble*, *Massucco Marble*) and from Ivrea-Verbano Zone (*Candoglia*, *Ornavasso*, *Valle Strona Marble*); marbles of the Dora-Maira Unit, both from Mesozoic sedimentary covers (*Foresto* and *Chianocco Marble*) and from pre-Mesozoic basement units (*Prali*, *Paesana* and *Brossasco Marble*); coloured marbles associated with ophi-carbonate bodies of the Liguria Piemonte Oceanic Domain (*Rosso Cesana*, 'Livernea Est' quarry). Moreover, hectometre-sized bodies of marble, originated by hydrothermal processes within the non-metamorphic Mesozoic Provençal-Dauphinois succession (Valdieri Marble, Bertok et al., 2019) were exploited as *Bardiglio di Valdieri* and *Cipollino di Valdieri*. The marbles of Piemonte were widely used in the past centuries throughout the region, and especially in Torino. A particular mention is due to the *Candoglia Marble*, exploited since the 14th century uniquely for the building and restoration of the Duomo di Milano. The *Aisone Stone* (Carraro et al., 1970), an impure marble charged in detrital quartz and feldspar grains, which derived from hydrothermal transformations of Cenozoic Alpine Foreland Basin sediments, has been included within the 'stone' class on the Main Map because it was only used as rough building material for local uses (polishing being hampered by the high content of siliciclastic grains).
- *Quartzite (qtz):* quartzite of supposed Permian – Early Triassic age occurs at the base of meta-sedimentary units of Alpine Axial Belt (Pre-Piemontese *Auct.*; Internal Briançonnais Units; Acceglio – Longet Unit; Ambin Massif; Dora – Maira Unit).

Quartzite of Jurassic age at the base of meta-sedimentary successions of oceanic units (Liguria – Piemonte Oceanic Domain and Valais Domain). The quartzite of the southern Dora Maira Unit was extensively quarried up to a few years ago (*Barge Quartzite*); quartzite of the same unit was also quarried for local uses in the Susa Valley (*Baume Quartzite*).

- *Metabasite (mbs):* these include the Mesozoic metabasite (meta-basalt, meta-gabbro, prasinite, amphibolite, eclogite) of oceanic units (Liguria – Piemonte Oceanic Domain and Valais Domain). Lenses of pre-Mesozoic metabasite intercalated in continental crust units (Argentera Massif; basement of Internal Briançonnais units; Dora Maira, Gran Paradiso and Monte Rosa units; Ambin Massif; Sesia Lanzo Zone) are also included. This class also comprehends the Paleozoic amphibolite with minor masses of meta-gabbro and serpentinite (Serie dei Laghi Complex) and migmatitic amphibolite with eclogite and granulite relics (Ivrea – Verbano Kinzigite Complex; Argentera Massif). Due to their discontinuous occurrence in outcrop and their mineralogical-textural heterogeneity, these rocks are not usually used as ornamental stones, apart from few local cases (e.g. Susa Valley *prasinite* widely used in the Sacra di San Michele abbey; see below).
- *Ultramafite and serpentinite (umf):* ultrabasic rocks, more or less metamorphosed, of the Lanzo and Voltri massifs, main masses of serpentinite (Liguria – Piemonte Oceanic Domain; Valais Domain; Sestri-Voltaggio Zone); meta-peridotite and serpentinite (Lepontine units, Cervandone – Geissfpad Complex; Sesia – Lanzo Zone, Rocca Canavese Unit; Canavese Zone, Pesmonte Serpentinite); more or less serpentinized mantle peridotite (Ivrea – Verbano Mafic Complex, Finero, Balmuccia and Baldissero bodies). Several ornamental stones, widely used in the twentieth century, were obtained from the ophicarbonates of the Liguria-Piemonte oceanic domain cropping out in the Cottian Alps (*Verde Acceglio, Verde Susa, Verde del Frejus, Verde e Rosso Cesana*) and in the Ligurian Apennine (*Verde Polcevera*). The *Laugera Stone* (used as a soapstone in the past) and the *Verde Oira*, a dark green serpentinised peridotite, are also included.
- *Graphite schist (grf)*: graphite-rich schist with lenses of pure graphite and graphite-bearing paragneiss (Dora – Maira Unit; monometamorfic '*Pinerolese Graphitic Complex*' Auct, Sandrone et al., 1993). Upper Carboniferous graphite-bearing phyllite of the Internal Briançonnais Units (Malusà et al., 2005). No ornamental stones from these lithotypes are reported on the map.
- *Micaschist s.l. (msc):* this class groups all metamorphic rocks of the pelitic system belonging to the pre-Mesozoic metamorphic basements of the Palaeo-European Continental Margin (Dora – Maira, Gran Paradiso, Monte Rosa units; Ambin Massif; Pre-piemontese units Auct.; Gran San Bernardo Unit; Lepontine units; Moncucco – Orselina-Isorno Unit), of the Palaeo-Adriatic Continental Margin (Sesia Lanzo Zone; Serie dei Laghi Complex) and of the Canavese Zone. Although this lithology is one of the most widespread in the western Alps, it has been used only locally (e.g. Forte di Fenestrelle; see below), due to its strong planar anisotropy.
- *Orthoderivate rocks s.l. (gne):* metamorphic rocks derived from late Paleozoic magmatic rocks of the polycyclic metamorphic basements of the Palaeo-European continental margin (Dora-Maira, Gran Paradiso, Monte Rosa units; Lepontine units). Jadeite-bearing orthogneiss of the Sesia – Lanzo Zone, Paleozoic orthoderivate (Serie dei Laghi Complex; Ambin Massif; Internal Briançonnais units) and Permian meta-volcanoclastite (Internal Briançonnais units) are also included.

A great number of ornamental stones derive from these lithotypes. These include the orthogneiss of the Dora-Maira Massif (Borghi et al., 2016), such as the *Luserna Stone*, widely used for roof coverings (e.g. dome of the Mole Antonelliana in Torino) and pavement/road flooring and still largely extracted at present, and other orthogneiss (*Malanaggio*, *Perosa*, *Cumiana* and *San Basilio stones*; *Borgone* and *Vaie gneisses*). Jadeite- and phengite-bearing orthogneiss have been exploited in the Sesia-Lanzo Zone (*Verde Jaco*, *Verde Selene*, *Verde Oropa*, the latter widely used in the Oropa Sanctuary). Several varieties of *Beola* and *Serizzo* orthogneiss are widely extracted in the Lepontine Units, such as *Beola Bianca*, *Grigia*, *Ghiandonata*, *Favalle*; *Serizzo Antigorio*, *Formazza*, *Sempione*, *Monte Rosa* (Cavallo et al., 2004a)

- *Migmatite (mig):* migmatitic rocks of various composition and texture (Argentera Massif; Ivrea – Verbano Kinzigite Complex). No ornamental stones from these lithotypes are reported on the map.
- *Granulite and high-grade schist (gra):* felsic granulite and quartz-feldspar-garnet paragneiss (Ivrea – Verbano Kinzigite Complex), sillimanite – garnet-bearing micaschist and paragneiss (Ivrea – Verbano Kinzigite Complex; Sesia – Lanzo Zone). No ornamental stones from these lithotypes are reported on the map.

2.1.4. Fault rocks

Fault rocks developed along main tectonic contacts have been grouped in one lithological class (*Tectonite, flt*). This class includes carnieule and tectonic breccia, mylonite of the Ferriere-Mollières shear zone (Argentera Massif; Compagnoni et al., 2010), and tectonites of the Canavese Zone (Fobello and Rimella Schist; Sacchi, 1977). Within the latter, two varieties of mylonitic orthogneiss were quarried (*White Quartzite*, *Verde Vogogna*).

3. Ornamental stone classification

The ornamental stones have been subdivided into six classes, each indicated by a different quarry symbol colour:

- sedimentary rocks: allochemical and orthochemical (yellow colour in Map).
- sedimentary rocks: terrigenous (brown colour in Map).
- 'granite' (red colour in Map): following the traditional commercial definition, this term refers to as quartz- and feldspar-bearing, mostly magmatic rocks, which receive polishing for ornamental purposes.
- 'stone' (grey colour in Map): following the traditional commercial definition, this term refers to as quartz- and feldspar-bearing metamorphic rocks which are used as ornamental stones without polishing.
- 'marble' (blue colour in Map): this term indicates only 'true' marbles, i.e. metamorphic rocks of carbonate composition. Non-metamorphic carbonate rocks traditionally included in the commercial definition of 'marble', have been here classed among 'sedimentary, allo-/orthochemical' rocks.
- mafic and ultramafic rocks (green colour in Map): metamorphic and magmatic rocks of mafic and ultramafic composition.

4. Quarry districts

The quarrying for ornamental stones of Piemonte can be subdivided into five main quarry districts (which include both active and inactive quarries) based on geographical and historical criteria (Figure 1):

- Verbano-Cusio-Ossola-Sesia Valley district: it includes the Lago Maggiore area and the Sesia and Ossola valleys in northeastern Piemonte. The main quarried lithotypes are represented by orthoderivate metamorphic rocks and granites (Boriani et al., 1988; Dino & Cavallo, 2014).
- Canavese – Biellese district: this district encompasses the northwestern Piemonte area between the Sesia and Orco valleys; the main varieties of ornamental stones are represented by magmatic and metamorphic lithotypes.
- Cottian Alps district: it corresponds to the Alpine segment comprised between the Stura di Lanzo and Grana valleys, where several varieties of metamorphic rocks (mainly orthoderivate from the Dora Maira Unit) were quarried.
- Maritime and Ligurian Alps district: it corresponds to the mountain area of southern Piemonte, where a wide variety of marble and sedimentary carbonate rocks were quarried, and includes the historic 'Monregalese' district (G.A.L. Mongioie, 2005).
- Southern Piemonte hills district: this district corresponds to the hilly sector of central and southeastern Piemonte, where some units of the Cenozoic sedimentary successions of the Tertiary Piemonte Basin were exploited as ornamental stones.

4.1. Quarries

The selection of quarries to be represented on the Main Map derives from the first comprehensive review of stone material made at the regional scale for Piemonte. Quarries and materials of historical, artistic and architectural interest have been selected (Figure 3).

Distinction was made between active and inactive quarry, based on the latest release of the official record of quarrying activities of the Piemonte Region (Regione Piemonte, 2019). Over the entire Region, 115 quarries have been mapped. For some lithotypes, which occur in a wide area and were subjected to a diffuse exploitment in many localities, only the largestor most significative quarries were mapped. As an example, for the *Pietra da Cantoni*, which counts tens of small quarries all over the eastern Monferrato hills (Sassone, 2005), only four main quarries were selected. Moreover, for the *Luserna Stone*, which counts 68 active quarries over the territory of three municipalities (Luserna San Giovanni; Rorà; Bagnolo Piemonte; Regione Piemonte, 2019), three quarry districts have been indicated, each corresponding to the territory of a municipality and comprehending several active quarries.

Each mapped quarry, indicated by a number on the Main Map, corresponds to an instance in the table of Supplementary File 1. This contains the basic information about the quarry site (quarry district, quarry state – active/inactive) and the quarried material (commercial name, petrographic name, rock type, age, tectonic unit – referred to as the *Tectonic Sketch Map* on the Main Map -, short petrographic description and main reference).

5. Representative monuments of Piemonte

Six historic buildings, chosen on the basis of their historical and architectural significance, have been reported on the Map (Figure 4) as significant examples of the use of ornamental stones.

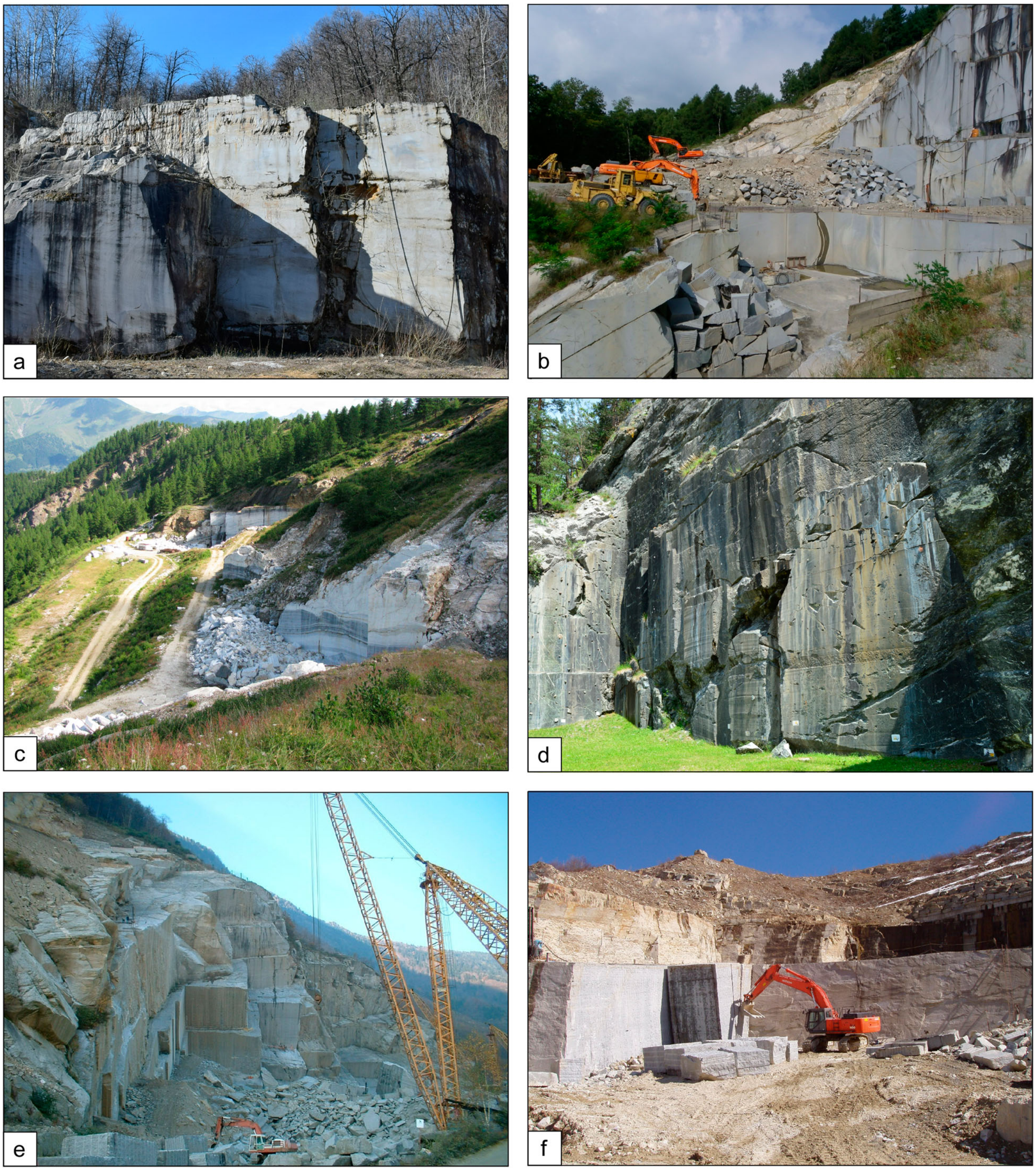

Figure 3. Examples of historical and contemporary quarries of Piemonte: (a) *Vico Stone* quarry, Vicoforte (CN) (photo by U. Storti); (b) *Vico Diorite* quarry, Vico Canavese (TO); (c) *Prali Marble*, Maiera quarries, Prali (TO); (d) *Verde Alpi Cesana*, 'palestra di roccia' quarry, Cesana Torinese (TO); (e) *Serizzo Antigorio*, Campieno Inferiore quarry, Crevoladossola (VB); (f) *Luserna Stone* quarry, Luserna San Giovanni (TO).

5.1. Sacra di San Michele

The Sacra di San Michele abbey, symbol of Piemonte region, was built between 10th and the 12th century around an outcrop of serpentinites on the top of Mount Pirchiriano, at the outlet of Susa Valley. Several local lithotypes, which are not traditionally used as ornamental stones, were adopted: serpentinite, augen gneiss, eclogite, calcschists, metagabbro, garnet-bearing chlorite-schist (Figure 4(a); Borghi et al., 2016). The perimeter walls of the abbey consist essentially of irregular blocks of serpentinite, prasinite (Liguria-Piemonte Oceanic Domain) and micaschist (Dora-Maira Unit). This monument is the result of several restorations; in 1836, after a strong earthquake, prasinite flying buttresses were added.

5.2. Basilica di Superga

The Basilica di Superga (1731) is a religious complex located on the Torino Hill and designed by the baroque

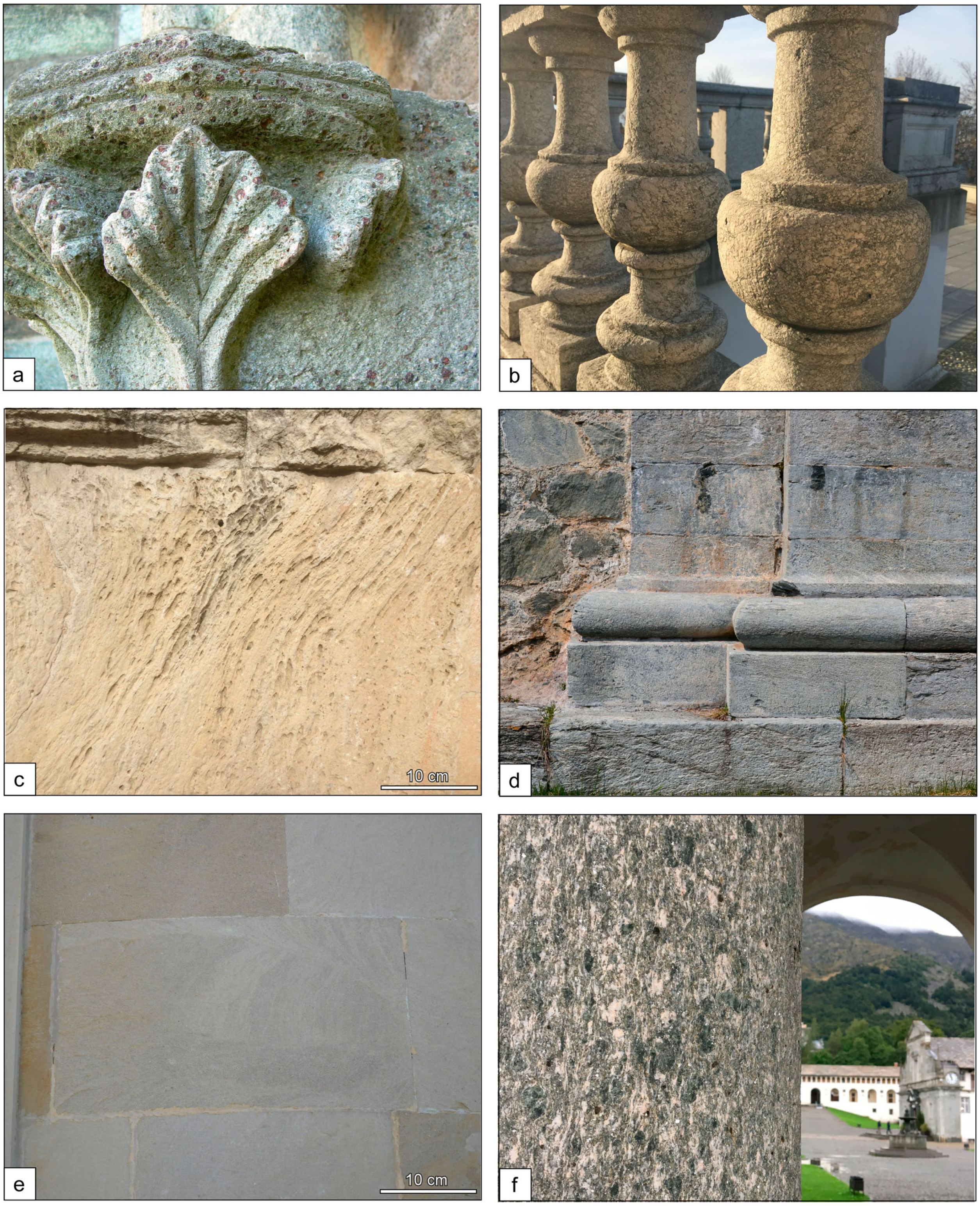

Figure 4. Details of six representative monuments of Piemonte: (a) capital of Sacra di San Michele made up of garnet-bearing chlorite-schist; (b) balustrade of Basilica di Superga made up of *Gassino Limestone*; (c) *Chianocco Marble* on the Palazzo Madama façade; (d) Governor Palace, Fenestrelle Fortress: basement in *Malanaggio Stone*; (e) *Vico Stone* on the Vicoforte Sanctuary façade; (f) Oropa Sanctuary courtyard column made up of *Verde Oropa*. The 'Basilica Vecchia' is visible to the right on the background.

architect Filippo Juvarra. Lithotypes exploited in the BTP, the Susa Valley and in the Ligurian Alps were used. The *Gassino Limestone* (Figure 4(b)) was adopted for the columns and the balustrade of the façade; the pavement in front of the façade is made up of *Balma Syenite*. In the interior, the dome is supported by two order of columns, the first made up of *Frabosa Marble* (shafts) and *Foresto Marble* (bases), the second of alternated columns made up of *Gassino Stone* and *Brossasco Marble*. The floor and the altars are enriched by several ornamental stones, including *Persichino di Corsaglia*, *Seravezza di Moncervetto*, *Busca Onyx* and *Verde Susa*.

5.3. Palazzo Madama

Palazzo Madama is a historical architectural complex located in the centre of Torino. The *Chianocco Marble* (Figure 4(c)) was used for almost the whole façade, while *Brossasco Marble* was employed for the statues and the vases of the apex, and *Frabosa Marble* for some pillars and the slab in the summit balustrade. For later restorations, *Prali Marble, Vaie Stone* and *Malanaggio Stone* were also adopted (Gambino et al., 2019).

5.4. Fenestrelle Fortress

The Fenestrelle Fortress is a group of military constructions, built between the 18th and the 19th centuries on the left side of Chisone Valley (Cottian Alps). Most of the material is represented by lithotypes cropping out on site and belonging to the Liguria-Piemonte Oceanic units (prasinite and calcschist) and to the Dora-Maira Massif (micaschist, augen gneiss, and *Malanaggio Stone*, Figure 4(d)) (Fiora et al., 2006).

5.5. Vicoforte Sanctuary

The Vicoforte Sanctuary (foothills of the Ligurian Alps), was commissioned in 1596 and completed in 1732. The rock used in the external construction was the the *Vico Stone* sandstone (Figure 4(e)), extracted nearby. The interior of the Sanctuary is enriched by important stone materials, including marbles and sedimentary carbonate rocks from the Maritime-Ligurian Alps district: *Frabosa Marble* (*Bigio, Nuvolato* and *Verzino* varieties), *Seravezza di Limone*, *Nero Ormea*, *Portoro di Nava*, *Bardiglio di Valdieri*, *Busca Onyx* and *Verde Polcevera* (Badino et al., 2001).

5.6. Oropa Sanctuary

The Oropa Sanctuary, close to the city of Biella, is the largest sanctuary dedicated to the Virgin Mary in the Alps, and a UNESCO World Heritage Site. The columns of the first and the second courtyards and the façade of the old 'Basilica Vecchia' are made up of *Verde Oropa* (Figure 4(f)), a jadeite-bearing orthogneiss of the Sesia-Lanzo Zone. The pavement and the balustrade of the entrance, as well as the columns of the later 'Basilica Superiore' are made up of *Balma Syenite*. Furthermore, the 'Basilica Vecchia' displays the employment of *serpentinite* for the columns of the façade and *prasinite* for the capitals.

6. Conclusions

The 1:250,000 Map of Ornamental Stones of Piemonte derives from the first comprehensive review of stone materials of the region. Besides scientific aspects, it represents a source of information for people operating in the fields of cultural heritage and geo-environmental sciences. The Map represents a lithological synthesis of a complex geological setting that comprehends a large number of lithotypes. Since the Map derives from the basic interactive GeoPiemonteMap (Piana, Barale, et al., 2017; Piana, Fioraso, et al., 2017) available on the Web, it provides an added informative value to the graphic documentation. The reader can effectively access more detailed information on the historical, geological and physical properties of rocks and stones, by querying the GeoPiemonteMap database, which has a structure compliant with that of the presented Map of Ornamental Stones.

Software

The geological map (polygons and lines) was compiled using QuantumGIS, version 2.18 Las Palmas. The final layout of the map, including the tectonic sketch and legend, was assembled using Canvas X GIS 2018 and Adobe Illustrator CS5 Version 15.1.0.

Geolocation Information

Piemonte region, NW Italy (44°03'36''N–46°27'52''N; 6°37'36''E–9°12'51''E).

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No potential conflict of interest was reported by the authors.

ORCID

Luca Barale http://orcid.org/0000-0002-8493-1974
Alessandro Borghi http://orcid.org/0000-0002-2545-0396
Anna d'Atri http://orcid.org/0000-0002-3560-1610
Francesca Gambino http://orcid.org/0000-0003-3744-5671
Fabrizio Piana http://orcid.org/0000-0001-7049-3160

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