Geoscience Canada
Journal of the Geological Association of Canada
Journal de l'Association Géologique du Canada

Heritage Stone 2. The Dora-Maira Unit (Italian Cottian Alps)
A Reservoir of Ornamental Stones Since Roman Times

Alessandro Borghi, Paola Cadoppi and Giovanna Antonella Dino

Volume 43, Number 1, March 2016

URI: https://id.erudit.org/iderudit/1035657ar

See table of contents

Publisher(s)

The Geological Association of Canada

ISSN

0315-0941 (print)
1911-4850 (digital)

Explore this journal

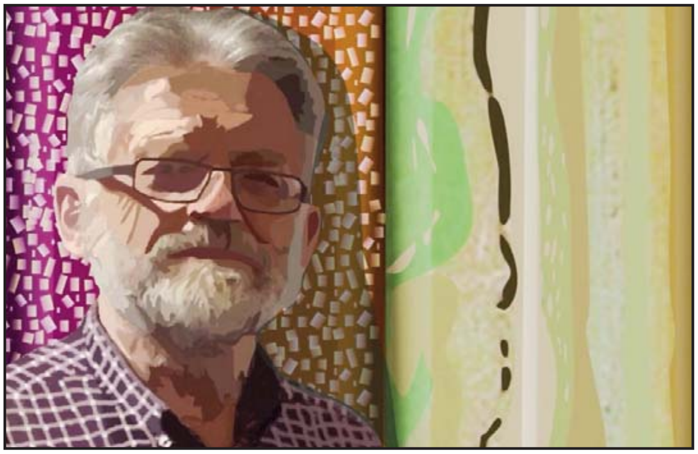
Cite this article

Borghi, A., Cadoppi, P. & Dino, G. A. (2016). Heritage Stone 2. The Dora-Maira Unit (Italian Cottian Alps): A Reservoir of Ornamental Stones Since Roman Times. *Geoscience Canada*, *43*(1), 13–30.

Article abstract

inner part of the Cottian Alps and belonging to the Penninic Domain of the Western Alps (northwestern Italy). It consists of a Paleozoic basement and its Mesozoic carbonate cover, metamorphosed under eclogite facies conditions in the Cenozoic. Due to the complexity of the rock associations and the textural-metamorphic transformations, the Dora-Maira Unit has been a source of ornamental stones over the centuries, and still represents a reservoir of material locally employed for historical and contemporary buildings. Several varieties of orthogneiss, quartzite and marble, derived from the Paleozoic basement and Mesozoic cover, are known by different local names (e.g. Luserna Stone, Borgone and Vaie Stone, Perosa Stone, Bargiolina Quartzite, Foresto and Chianocco Marble). These stones were largely employed during the 17th and 18th centuries for some of the most famous and important monuments in Turin (capital of Piedmont region, northwestern Italy), as well as in the countryside, since Roman times. Some of the materials exploited in the Dora-Maira Unit were also exported to foreign countries: Borgone and Vaie Stone were used for the paving of the Louvre Museum, and Perosa Stone was employed for the construction of the monument of Independence in Lagos, Nigeria. Consequently, the Dora-Maira Unit can be designated as a Global Heritage Stone Province.

SERIES



Heritage Stone 2. The Dora-Maira Unit (Italian Cottian Alps): A Reservoir of Ornamental Stones Since Roman Times*

Alessandro Borghi[+], Paola Cadoppi and Giovanna Antonella Dino

Department of Earth Sciences, University of Turin
Via Valperga Caluso, 35, 10125 I-Turin, Italy
[+]E-mail: alessandro.borghi@unito.it

SUMMARY

The Dora-Maira Unit is a geological unit cropping out in the inner part of the Cottian Alps and belonging to the Penninic Domain of the Western Alps (northwestern Italy). It consists of a Paleozoic basement and its Mesozoic carbonate cover, metamorphosed under eclogite facies conditions in the Cenozoic. Due to the complexity of the rock associations and the textural-metamorphic transformations, the Dora-Maira Unit has been a source of ornamental stones over the centuries, and still represents a reservoir of material locally employed for historical and contemporary buildings. Several varieties of orthogneiss, quartzite and marble, derived from the Paleozoic basement and Mesozoic cover, are known by different local names (e.g. *Luserna Stone, Borgone* and *Vaie Stone, Perosa Stone, Bargiolina Quartzite, Foresto* and *Chianocco Marble*). These stones were largely employed during the 17^{th} and 18^{th} centuries for some of the most famous and important monuments in Turin (capital of Piedmont region, northwestern Italy), as well as in the countryside, since Roman times. Some of the materials exploited in the Dora-Maira Unit were also exported to foreign countries: Borgone and Vaie Stone were used for the paving of the Louvre Museum, and Perosa Stone was employed for the construction of the monument of Independence in Lagos, Nigeria. Consequently, the Dora-Maira Unit can be designated as a Global Heritage Stone Province.

RÉSUMÉ

L'Unité Dora-Maira est une unité géologique affleurant dans la partie interne des Alpes Cottiennes; elle appartient au Domaine Penninique des Alpes occidentales (Italie du Nord-Ouest). Elle se compose d'une croûte continentale d'âge Paléozoïque supérieur et de sa couverture carbonatique Mésozoïque, métamorphosées en faciès éclogite pendant le Cénozoïque. En raison de la complexité des associations lithologiques et des transformations métamorphiques et structurelles, l'Unité Dora-Maira a été une source de pierres ornementales au cours des siècles, et encore il représente un réservoir de matériau employé localement pour des bâtiments contemporains et historiques. Plusieurs variétés de gneiss, de quartzite et de marbre, provenant du socle paléozoïque et de la couverture mésozoïque et connues sous différents noms locaux (par exemple Pierre de Luserna, Pierre de Borgone et Vaie, Pierre de Perosa, Bargiolina, marbres de Foresto et Chianocco), étaient largement utilisées pour certains monuments les plus célèbres et importants à Turin (capitale de la région Piémont), au cours des 17ème et 18ème siècles, et dans les alentours de la ville depuis l'époque romaine. Certains des matériaux exploités dans l'Unité Dora-Maira ont été également exportés aux pays étrangers: la Pierre de Borgone et Vaie a été utilisée pour le pavage du Musée du Louvre, et la Pierre de Perosa a été employé en Afrique, à Lagos, au Nigéria, pour la construction du monument de l'indépendance. Par conséquent, l'Unité Dora-Maira peut être indiquée comme une Pierre Province du patrimoine mondial.

*This article is part of a set of papers dedicated to the memory of Anders Wikström published in Geoscience Canada Special Issue: Heritage Stone; a new series that is guest edited by Dolores Pereira and Brian R. Pratt.

Geoscience Canada, v. 43, http://www.dx.doi.org/10.12789/geocanj.2016.43.084 pages 13–30

INTRODUCTION

Stone has always been a major source of material in the Italian construction industry and an important cultural element for the creation of masterpieces of sculpture and architecture, thus constituting a significant part of Italy's cultural heritage. Knowledge of stone resources, their mineralogic and petrographic characteristics and their use, can provide a broad overview of the historical relevance of these materials, emphasizing the importance of a significant economic activity that is fundamental to the understanding of the history and the traditions of different Mediterranean cultures (Cooper 2015; Marker 2015).

Every Italian region is represented by artistic creations and historic buildings often made of historic heritage stone. In particular, in the Piedmont region (northwestern Italy), stone has always been the most widely employed building material characterizing, for example, the architectural identity of the city of Turin (capital of Piedmont). Here, stones have been used in historical and contemporary buildings, monuments and urban art, showing the close link between an urban area and natural stone resources, and emphasizing the role that stone has played in the culture and economic wealth of the Piedmont region (Borghi et al. 2015).

From the Roman age to the 18th century the easily workable materials (e.g. marble and sedimentary rocks) were exploited and used for valuable infrastructures and sculptures. Lately, during the 19th century, with the development of new technologies for dimension stone exploitation and processing, granite and other silicate rocks have been progressively employed. The knowledge of stone resources (mineralogical and petrographic features, their use and exploitation techniques, etc.), therefore enhances the historical and cultural significance of such materials. The great variety of ornamental and building stones used for architectural elements is certainly a result of the complex geological nature of the region (Borghi et al. 2014). In Piedmont, indeed, many different geological units occur, in particular, the western part of the metamorphic Alpine Chain, the sedimentary Tertiary Piedmont Basin, and a small sector of the Northern Apennines.

This paper illustrates the most important lithological varieties of cultural stone coming from the Dora-Maira Unit, which extends more than 1000 km^2 in the inner part of the Western Alps (Fig. 1). A lithological and textural characterization and an overview of the main applications are provided for the selected rock types.

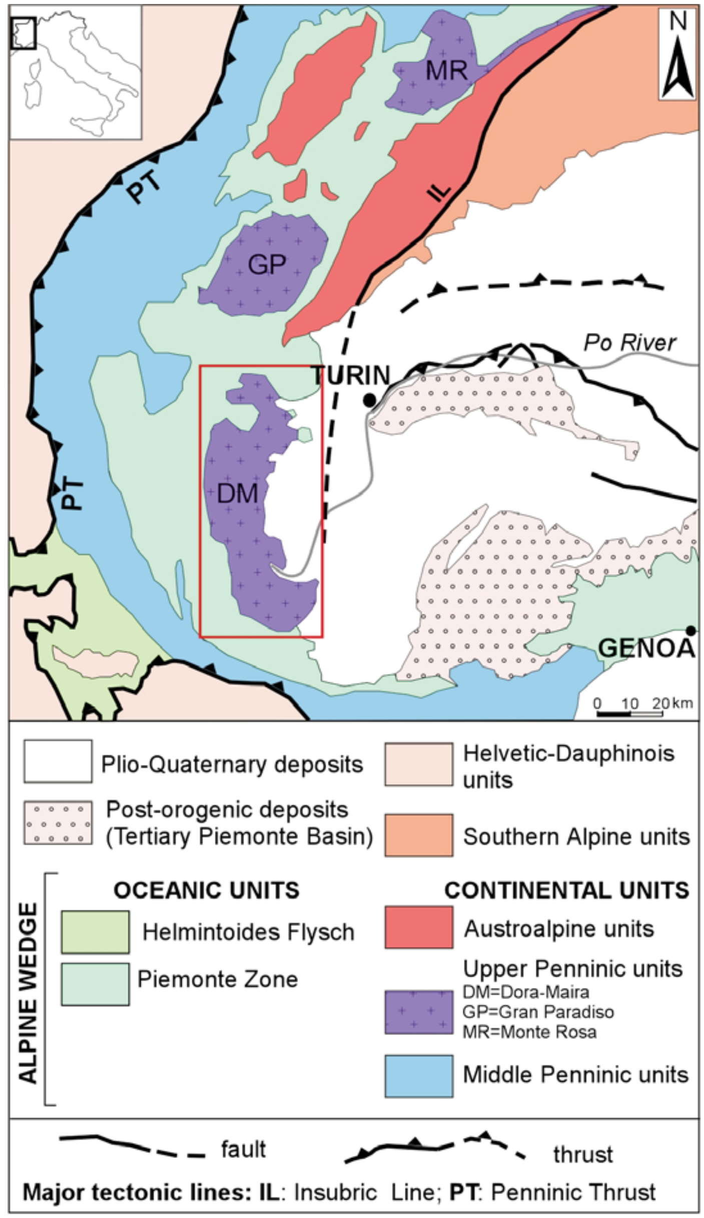


Figure 1. Geological map of the Western Alps (modified after Fusetti et al. 2012). The red rectangle points out the area represented in Figure 2.

GEOLOGICAL SETTING

The Western Alps represent a collisional orogenic wedge where both continent- and ocean-derived tectonic units are currently exposed. It consists of three main structural domains: (1) the internal domain, belonging to the upper plate of the collisional system, which corresponds to the Southern Alps; (2) the external domain, representing the European foreland and consisting of the Helvetic–Dauphinois domain; and (3) the axial sector of the chain, included between the Penninic Front to the north, and the Insubric Line to the south (Fig. 1) (Dal Piaz et al. 2003). The axial portion represents a composite nappe pile consisting of the Austroalpine and Penninic domains separated by oceanic units of the Piemonte Zone.

The Dora-Maira Unit, together with the Monte Rosa and the Gran Paradiso Massifs, represents the basement nappe of the inner Penninic Domain (e.g. Schmidt al. 2004) and consists of various tectonic slices of pre-Triassic basement and metasedimentary successions of Permo–Mesozoic cover. This unit underwent a strong Alpine tectono-metamorphic overprint characterized by high (HP) to ultra-high pressure (UHP) metamorphic assemblages and greenschist re-equilibration in Cenozoic time (Sandrone et al. 1993; Compagnoni et al. 2004). Because of the complexity of the rock associations and the textural-metamorphic transformations, the Dora-Maira Unit was, and still is, the object of extensive exploitation (Fig. 2; Table 1).

The pre-Triassic basement is represented by poly- and monometamorphic complexes, both intruded by late Variscan granitoids. The polymetamorphic complex (9 in Figure 2), mainly consists of garnet–chloritoid micaschists, minor metabasites, impure dolomitic marble, and granodioritic

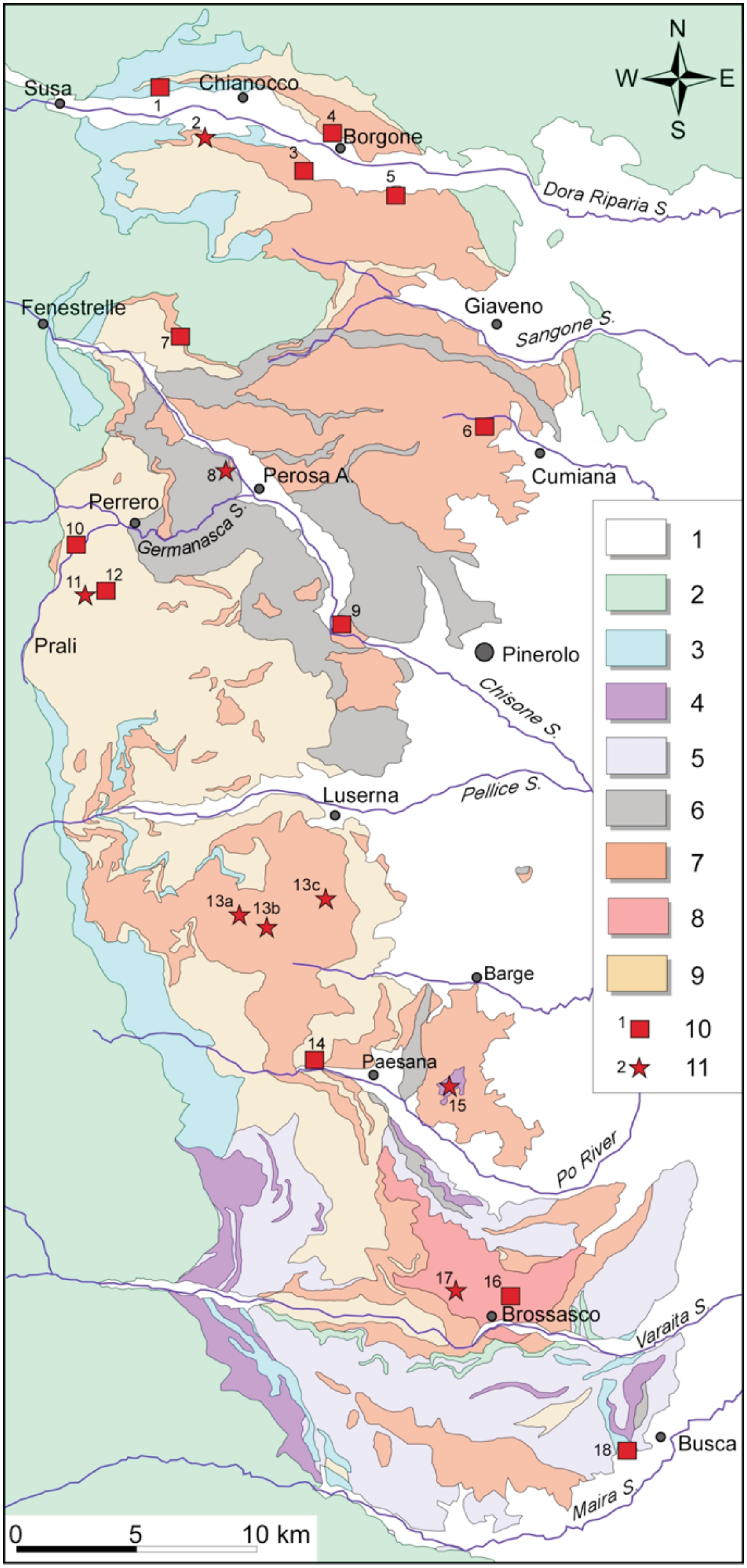


Figure 2. Geological map and quarry location of the most representative ornamental and building stones exploited in the Dora-Maira Unit. Map legend: 1) undifferentiated Quaternary deposits; 2) Piemonte ophiolite nappe (undifferentiated) and minor slices within the Dora-Maira Unit; 3) Mesozoic cover (marble, metadolomite and calcschist); 4) impure quartzite ('Bargiolina'); phengite-quartzite grading into quartz micaschist and phengite-schist (Permian?); 5) fine-grained gneiss and micaschist, including thin lenses of quartzite and rare bodies of blueschist facies metabasite (Permian?); 6) graphite-bearing micaschist, meta-arenite, and meta-conglomerates ('Pinerolese Graphitic Complex,' Carboniferous?); 7) meta-intrusive rocks of different age and composition; 8) orthogneiss and meta-granitoid, coarse-grained garnet micaschist, pyrope-coesite quartzite, silicate marble and metabasite with ultra-high pressure re-equilibration (Brossasco−Isasca Complex); 9) polymetamorphic garnet-chloritoid micaschist, impure marble, eclogite facies metabasite (mostly re-equilibrated into greenschist facies), and relics of pre-Alpine high temperature assemblages (pre-Carboniferous?); 10) historical quarries; 11) quarries still active in the last decade. The description of each quarry site is in Table 1. Geological map after Vialon (1966), Sandrone et al. (1993), Balestro et al. (1995), Bussy and Cadoppi (1996), Carraro et al. (2002), and Compagnoni et al. (2012).

Table 1. Location and description of the main lithotypes exploited in the Dora-Maira Unit.

Quarry site in fig. 2	Name	Lithology	Paragenesis	Fabric	Age
1	Foresto and Chianocco Marble	Dolomitic marble	Dol - Cal - Wmca	Foliated	Triassic
2 3	S. Basilio Stone Villar Focchiardo Stone	Leucocratic orthogneiss	Qtz – Ab – Kfs – Wmca – Tur	Gneissic layering	Late Variscan
4 5	Borgone Stone Vaie Stone	Metagranite-augengneiss	Qtz – Ab – Kfs – Wmca – Bt	Gneissic layering to poorly foliated	Late Variscan
6	Cumiana Stone	Orthogneiss	Qtz – Ab – Kfs – Wmca – Bt – Ep	Gneissic layering	Late Variscan
7	Luserna type Stone	Orthogneiss	Qtz – Ab – Kfs – Wmca ± Bt ± Chl	Tabular foliation	Late Variscan
8 9	Perosa Stone Malanaggio Stone	Dioritic- to granodioritic gneiss	Pl – Am – Ep – Chl – Bt – Wmca ± Qtz ± Kfs	Gneissic layering	Late Variscan
10 11 12	Salza di Pinerolo Marble Prali Marble Prali Marble	Impure to layered marble	Dol – Cal – Tr ± Chl ± Ep ± Wmca	Foliated	Paleozoic
13a 13b 13c	Luserna Stone Basin (Luserna S. Giovanni, Rorà and Bagnolo municipalities)	Orthogneiss	Qtz – Ab – Kfs – Wmca ± Bt ± Chl	Tabular foliation	Late Variscan
14	Paesana Marble	Impure to layered marble	Dol – Cal – Wmca – Tr	Poorly foliated	Paleozoic
15	Bargiolina	Quartzite	Qtz – Wmca – Ab	Tabular foliation	Permo-Triassic
16	Brossasco Marble	Silicate marble	Cal ± Dol ± Cpx ± Ph ± Ep ± Grt ± Phl	Isotropic to poorly foliated	Paleozoic
17	Gilba Stone	Orthogneiss	Pl + Qtz + Kfs + Ph ± Bt	Strongly foliated	Late Variscan(?)
18	Busca Alabaster	Speleothem	Cal	Columnar and fibrous	Quaternary

Ab=albite, Am=amphibole, Bt=biotite, Cal=calcite, Chl=chlorite, Cpx=clinopyroxene, Dol=dolomite, Ep=epidote, Grt=garnet, Kfs=K-feldspar, Ph=phengite, Phl=phlogopite, Pl=plagioclase, Qtz=quartz, Tur=tourmaline, Tr=tremolite, Wmca=white mica

orthogneisses of pre-Variscan age (457 ± 2 Ma; Bussy and Cadoppi 1996). Pre-Alpine relics, attributed to Variscan metamorphism, are represented by garnet–muscovite–sillimanite pseudomorphs after cordierite, spinel, andalusite and staurolite in the micaschists (Cadoppi 1990; Compagnoni et al. 1993); red biotite in the orthogneiss; and diopside in the marble (Cadoppi 1990). An important talc mineralization, presently exploited in the Germanasca Valley, is hosted in this complex. The polymetamorphic complex was metamorphosed under eclogite facies conditions at 15−20 kbar and 500−550°C (Borghi et al. 1985; Pognante and Sandrone 1989; Cadoppi 1990; Chopin et al. 1991; Borghi et al. 1996; Gasco et al. 2011), though a diffuse re-equilibration to greenschist facies affects the Dora-Maira Unit as a whole. During the past and in the last decade, the only rock type exploited in this complex has been dolomitic marble cropping out in metre-sized lenses within the micaschist (quarry sites 10, 11, 12 and 14 in Figure 2).

A coesite-bearing polymetamorphic complex, the so-called Brossasco−Isasca Complex (8 in Figure 2; Kienast et al. 1991), occurs in the southern Dora-Maira Unit. It has been distinguished, from all the other basement complexes, thanks to its peculiar metamorphic assemblage (Chopin 1984; Chopin et al. 1991). This complex consists of orthogneiss and subordinate metapelite, silicate marble and metabasite that underwent UHP metamorphism at 35 Ma (Gebauer et al. 1997; Compagnoni et al. 2004). In the Brossasco−Isasca Complex, two dimension stones are exploited: the *Brossasco Marble* and a mylonitic orthogneiss called *Gilba Stone* (quarry sites 16 and 17 in Figure 2).

Among the monometamorphic complexes, the 'Pinerolo Graphitic Complex' is noteworthy (Vialon 1966; Borghi et al. 1984; Henry et al. 1993). It is exposed in the innermost sector of the unit and represents the deepest tectonic element. It consists of locally graphite-rich metapelite, fine-grained gneiss, and metaconglomerate, probably of Carboniferous age (6 in Figure 2). Pressure-temperature (P−T) estimates for this complex are scarce but suggest a re-equilibration stage at 530−550°C and 6.0−7.5 kbar in the metapelite (Avigad et al. 2003) and development of blueschist facies assemblages (Borghi et al. 1985; Wheeler 1991). Another monometamorphic complex is present in the central-southern sector of the Dora-Maira Unit (partly corresponding to the Dronero and Sampeyre complexes of Vialon 1966); it is mainly represented by fine-grained micaschist and gneiss, chloritoid-rich micaschist, quartzite, and rare basic rocks (4 and 5 in Figure 2). Among these lithotypes, a variety of quartzite known as *Bargiolina* in the Monte Bracco area (Barge and Sanfront municipalities) is still exploited (quarry site 15 in Figure 2).

Various meta-intrusive rock types of granitic to dioritic composition, mainly attributed to the late-Variscan magmatic

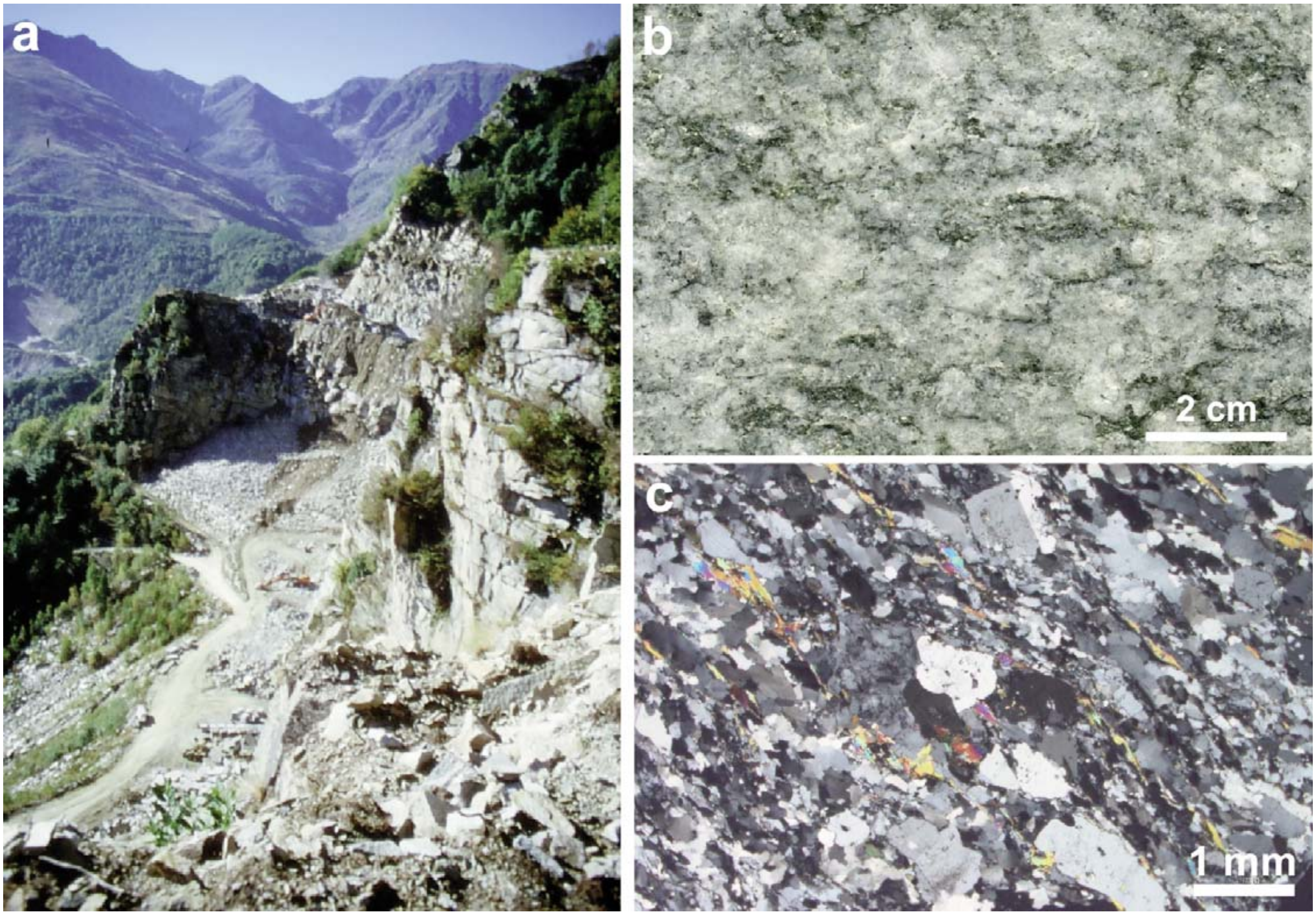


Figure 3. Luserna Stone: a) Quarry site in the Pellice Valley, Rorà municipality (site 13a in Figure 2); b) macroscopic aspect of the rock, characterized by a natural split surface defined by white mica, chlorite and biotite; c) microscopic aspect (crossed-polarized light), marked by the presence of magmatic K-feldspar porphyroclasts, enveloped by Alpine tectonic foliation.

event (Bussy and Cadoppi 1996), intruded both the polymetamorphic and monometamorphic complexes (7 in Figure 2). Since these orthogneisses have been in the past and are still the most widely exploited rock types (see quarry sites 2, through 9, 13a, b, c, and 17 in Figure 2), their detailed description is presented.

On top of the poly- and monometamorphic complexes, slices of the Permo–Mesozoic cover succession are preserved (3 in Figure 2). These are characterized mainly by quartzite or other siliciclastic layers in the lower part and carbonate sequences represented by dolomitic marble and calcschist in the upper part (Cadoppi and Tallone 1992; Cadoppi et al. 2002). In the Susa Valley (Dora-Riparia basin), dolomitic marble (*Foresto* and *Chianocco Marble*) is the exploited rock type (quarry site 1 in Figure 2).

Lastly, in the Mesozoic carbonate cover in the southern part of the Dora-Maira Unit (quarry site 18 in Figure 2), the *Busca onix* is present. It represents a Quaternary speleothem of calcite composition (Marengo et al. 2014) that fills narrow fractures in a dolomitic marble. This material was employed between the 16th and 17th centuries exclusively as ornamental stone and is not described here.

STONE DESCRIPTION

The ornamental and building stones quarried in the Dora-Maira Unit are grouped into two main categories: 1) silicates, which include all the orthogneisses and the quartzites; and 2) carbonates, which consist of all the marble varieties present in the region.

Silicate Stones

The most representative and most employed silicate stone in historical and current applications is the Luserna Stone, an orthogneiss derived from leucogranite of Permian age. It crops out over a large area (approximately 50 km^2) in the Cottian Alps, on the border between Turin and Cuneo Provinces (locations 13a, b, and c in Figure 2). The Luserna Stone quarries are located in the Bagnolo Piemonte, Rorà and Luserna S. Giovanni municipalities, at altitudes that range between 900 and 1500 m above sea level (a.s.l.) (Fig. 3a). At present, the Luserna Stone is the most important dimension stone quarried from the Dora-Maira Unit. Its overall annual production is nearly 330,000 t (≅125,600 m^3) of 'workable stone' and about 512,000 t (≅194,000 m^3) of rip-rap and armour stone (Sandrone et al. 2004). At the hand sample level, *Luserna Stone*

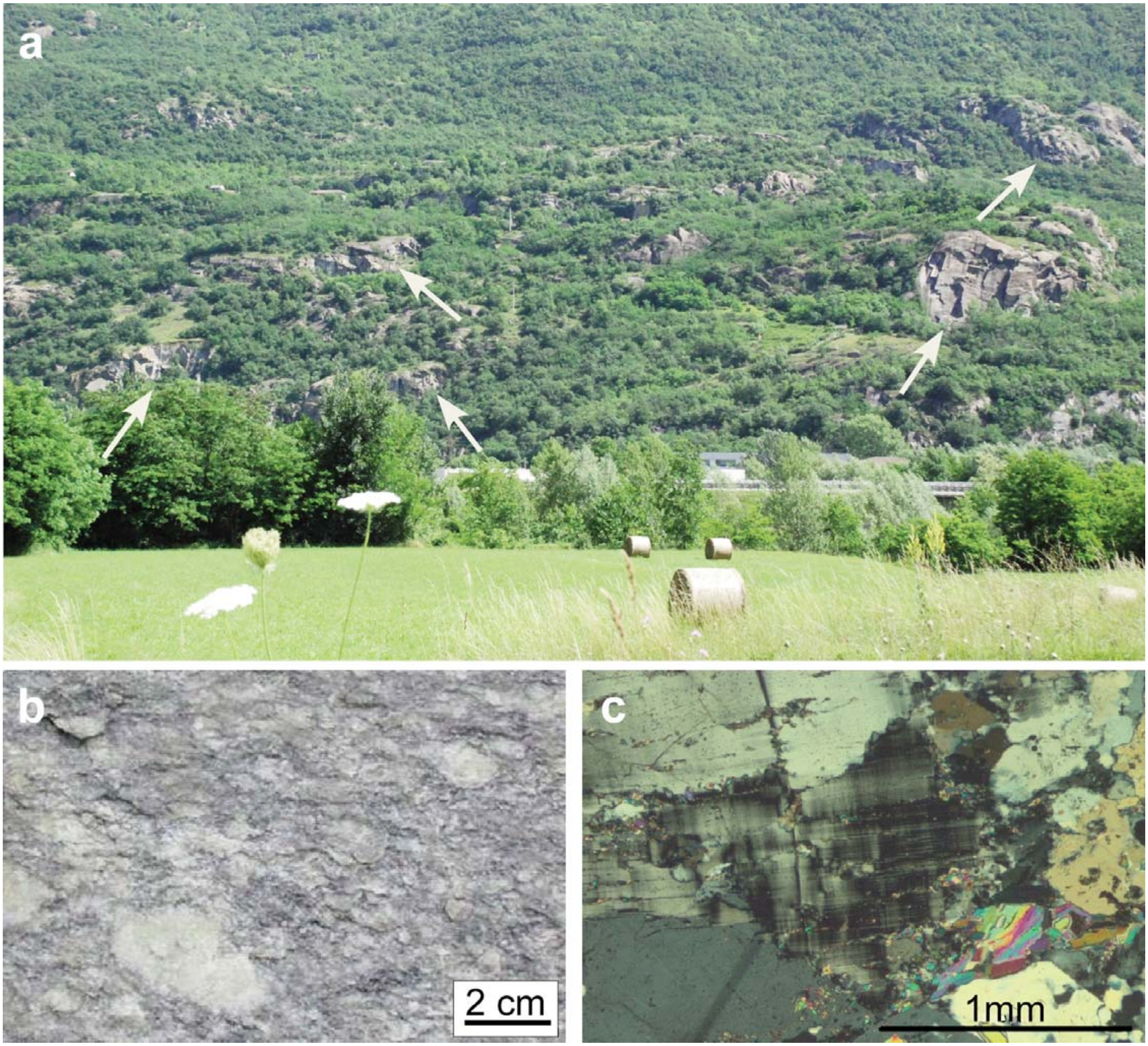


Figure 4. Borgone Stone: a) Ancient quarry sites along the northern slope of the lower Susa Valley (site 4 in Figure 2); b) macroscopic aspect of the rock, characterized by large K-feldspar porphyroclast of magmatic origin: c) microscopic aspect (crossed-polarized light), marked by the occurrence of microcline porphyroclasts.

shows a light grey colour; it is fissile and easy to split along schistosity planes defined by the iso-orientation of phyllosilicates (Fig. 3b). The phyllosilicates are mainly represented by white mica crystallized under high pressure conditions and, in smaller quantities, biotite and chlorite (Fig. 3c). Magmatic porphyroclasts, represented by K-feldspar, in addition to quartz and albite, partially recrystallized during the Alpine metamorphic event, impart a micro-augen texture to the rock (Sandrone et al. 2000).

In the past, the lower Susa Valley was characterized by the presence of numerous quarries, important for the exploitation of gneisses, namely the *Borgone* (Fig. 4a), *Vaie* and *Villar Focchiardo stones* (quarry sites 3, 4, 5, respectively, in Figure 2) (Barisone et al. 1992). The discovery of prehistoric objects near the Vaie quarry site suggests that this material was employed during the Bronze Age; it was certainly used during the Roman age (Fiora and Gambelli 2003). At present only the *San Basilio Stone* quarry, located in Bussoleno (west of Chianocco and 50 km northwest of Turin), is active (quarry site 2 in Figure 2; Fig. 5a). This rock, corresponding to the historic Villar Focchiardo Gneiss, consists of a tourmaline-rich leucocratic orthogneiss, and is light grey in colour. It is characterized by a granitic composition and shows a foliation defined by mica lamellae and the orientation of tourmaline blasts (Fig. 5b, c). Typical production is about 10,000 m^3/yr (Sandrone et al. 2004). Borgone and Vaie stones are represented by a metagranite having a porphyritic, slightly foliated texture (Fig. 4b, c). K-feldspar porphyroclasts are embedded in a recrystallized

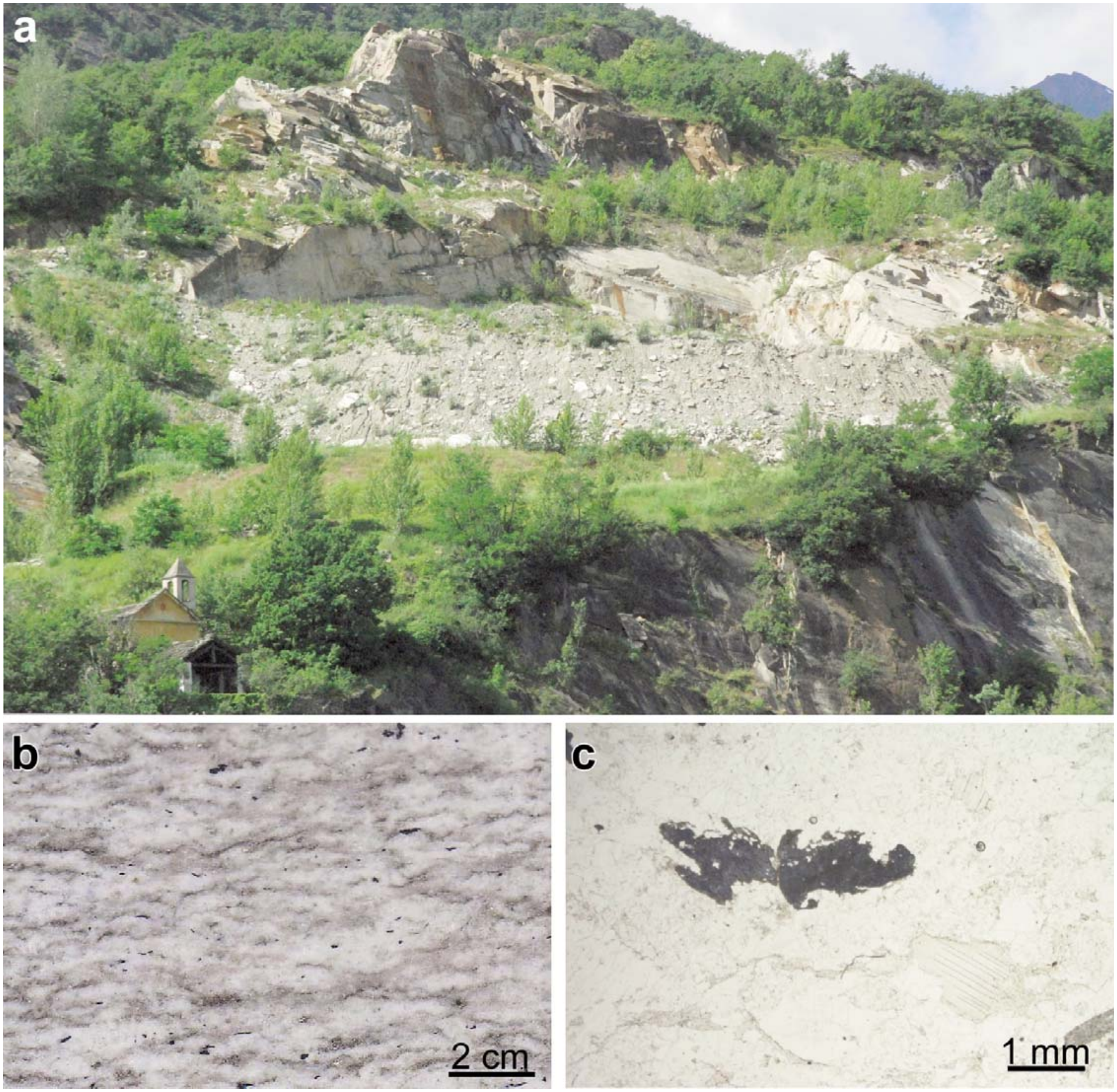


Figure 5. San Basilio Stone: a) Active quarry located along the southern slope of the lower Susa Valley (site 2 in Figure 2); b) macroscopic aspect of the rock, characterized by a mineralogical lineation defined by tourmaline; c) microscopic aspect (plane-polarized light), marked by the presence of pleochroic tourmaline crystal.

matrix mainly consisting of quartz and albite, in addition to white mica and minor biotite. Epidote and rare garnet, representing the metamorphic products of magmatic plagioclase, are also present. Allanite, zircon, monazite and apatite occur as accessory minerals. The main difference between these two stone varieties is the presence of primary muscovite (partially replaced by phengite) in the Vaie Stone (Cadoppi 1990).

Another important orthogneiss exploited in the Dora-Maira Unit is the *Cumiana Stone* (quarry site 6 in Figure 2). It consists of millimetre-sized K-feldspar porphyroclasts surrounded by a foliated matrix of quartz, white mica, biotite, albite and epidote (Fig. 6a, b). This variety of rock is no longer quarried and can be observed only in historical monuments.

The so-called *Malanaggio Stone* is an amphibole–biotite orthogneiss of quartz-dioritic composition that intruded the Pinerolo Graphitic Complex ca. 288−290 Ma (Bussy and Cadoppi 1996). Quarrying activities began in the early 19th century with the opening of five quarries located in the Porte and Perosa Argentina area (Chisone Valley); after World War II, because of the low demand for stone materials and the

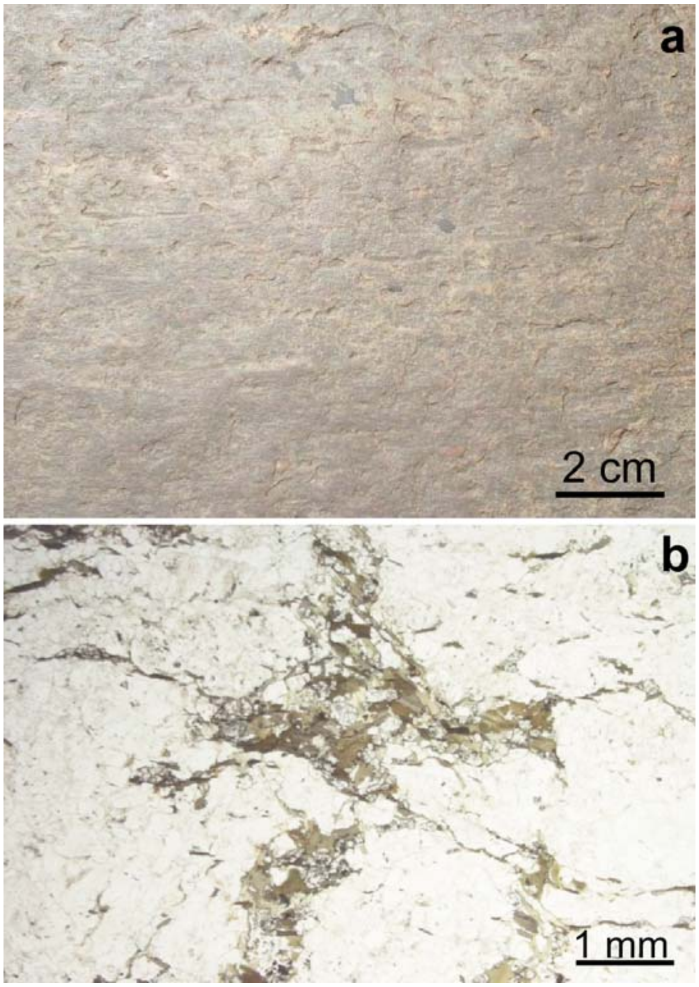


Figure 6. Cumiana Stone: a) Macroscopic aspect of the rock, characterized by alteration of feldspars; b) microscopic aspect (plane-polarized light), marked by the occurrence of biotite flakes.

decreased availability of manpower, some of these quarries were closed (quarry site 9 in Figure 2). At present only the quarry of the so-called *Perosa Stone* is active; it is located in the Brandoneugna village near Perosa Argentina (Chisone Valley) (quarry site 8 in Figure 2; Fig. 7a). The Perosa Stone is similar to the Malanaggio Stone and is distinguished mainly by the presence of white mica (which is absent in the historic variety) defining the main schistosity. The rock consists primarily of quartz, plagioclase, chlorite, biotite, hornblende, zoisite and clinozoisite; garnet, apatite and titanite occur as accessory minerals (Fig. 7b, c). The microstructure is weakly foliated; in places, the original sites of magmatic amphibole and plagioclase (mainly oligoclase/andesine) can still be recognized. Bargiolina Quartzite is another important dimension stone quarried in the Dora-Maira Unit, and it is exploited along the western slope of the Monte Bracco (in the Barge and Sanfront municipalities east of Paesana village), in the lower Po Valley (quarry site 15 in Figure 2). Geologically, it represents Permo–Triassic quartzarenites deposited during the post-Variscan marine transgression and subjected to Alpine-age metamorphism (Vialon 1966). It is a micaceous, fine-grained quartzite that displays a tabular and homogeneous appearance (Fig. 8a). The Bargiolina – known and used since prehistoric times as a substitute for flint, and celebrated by Leonardo da Vinci (Fiora et al. 2002) – has been intensely exploited since the early 20th century. There are different colour varieties of the Bargiolina: golden yellow, pale yellow, olive-grey, grey and white (marmorina variety). The quartzites, several metres thick, have been quarried as dimension stone by different companies, both in the Barge and Sanfront areas (Dino et al. 2001). At present, its market is much reduced by competition from Brazilian quartzite, and thus it is now exploited only in small quantities (5000 t of 'workable stone' in 2002) at a single quarry in Barge village (Province of Cuneo) (Sandrone et al. 2004). The Bargiolina contains thin layers of phengite that impart a regular schistosity, and consequently splits into very thin slabs (1–2 cm) (Fig. 8b, c).

Carbonate Stones

The Alpine marbles (both white and coloured) were widely employed in Turin for indoor as well as outdoor prestigious applications, especially until the end of the 18th century, when the carbonate stones, albeit easier to work, were gradually replaced by silicate rocks. Most of the marble from Piedmont have been exploited in the Western Alps. They generally crop out as small lenses intercalated in schist and gneiss belonging to various geological units and characterized by different metamorphic conditions. Four historical marbles, named *Foresto*, *Chianocco, Prali* and *Brossasco*, can be recognized in the Dora-Maira Unit. The Prali and Brossasco Marble belong to the polymetamorphic basement, whereas the Foresto and Chianocco Marble come from the Permo–Mesozoic metasedimentary succession, only affected by Alpine metamorphism.

The most important white marbles are Triassic−Early Jurassic dolomitic white marbles from Susa Valley (Foresto and Chianocco Marble), known and used since Roman times (quarry site 1 in Figure 2; Fig. 9a, b). The marble is finely crystalline, has a planar fabric, and is white to ice-grey in colour (Fig. 9c). It consists mostly of dolomite, although calcite crystals occur. White phengitic mica and chlorite define the anisotropy of the rock (Fiora and Audagnotti 2001) (Fig. 9d).

The Prali Marble has been quarried in the Germanasca Valley (quarry sites 10, 11 and 12 in Figure 2) since the 14th century and was also known as Perrero or Faetto Marble (Peretti 1938). The Rocca Bianca quarry (quarry site 12 in Figure 2; Fig. 10a, b), with exploitation beginning in 1584 and lasting until 1968, was the most important one in terms of quantity of exploited material. Since 1981, the marble has been occasionally extracted in the Maiera Quarry (western slope of the Rocca Bianca, quarry site 11 in Figure 2; Fig. 10c); its production has been several hundred cubic metres per year. Prali Marble has a banded structure characterized by white to grey layers and local occurrences of green veins formed by phyllosilicates (Fig. 10d). It is a predominantly finely crystalline calcitic marble forming several transposed layers (up to a few metres thick) embedded within garnet- and chloritoid-bearing micaschist (Cadoppi et al. 2008). In dolomite-rich domains it is locally characterized by centimetre-thick tremolite-rich layers (Fig. 10e).

Last, the Brossasco Marble, crops out in the middle Varaita Valley (quarry site 16 in Figure 2) and was intensively exploited from about 1600 to 1700. It lies within the Brossasco Isasca Complex in the southern part of the Dora-Maira Unit. It is a coarsely crystalline isotropic marble consisting of calcite and

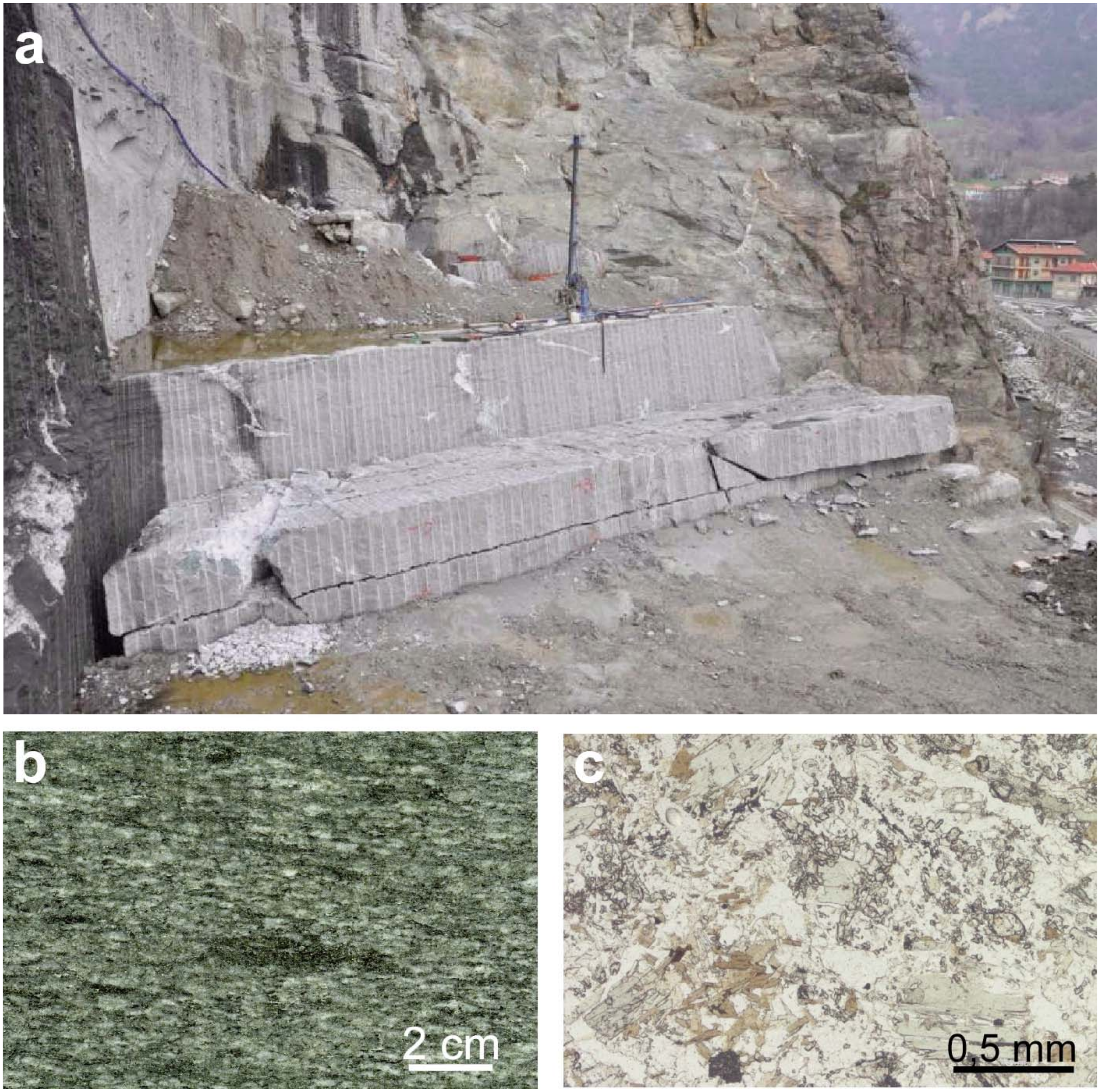


Figure 7. Perosa Stone: a) Active quarry located along the eastern slope of the Chisone Valley (site 8 in Figure 2); b) macroscopic aspect of the rock, characterized by tectonic foliation underlined by melanocratic inclusions; c) microscopic aspect (plane-polarized light), marked by the association of plagioclase, amphibole, epidote, chlorite and biotite.

minor dolomite, and formed under high-grade metamorphic conditions (over 700°C). The marble has a massive, largely saccharoidal texture (Fig. 11a, b). Also present are garnet (reddish brown), omphacite (light green), amphibole (dark green), white mica, and locally phlogopite (brown) associated with carbonate phases.

HISTORICAL EMPLOYMENTS

Because of the different varieties of rock present, the Dora-Maira Unit can be considered a reservoir of ornamental and building stones, employed locally since Roman times for military and religious buildings. Furthermore, these materials were used in the Piedmont region for the construction of important historical palaces (especially in the 17th and 18th centuries).

Countryside

One of the more striking examples of Dora-Maira stone applications during the Roman age is the Arch of Augustus at Susa, built by King Cozio to celebrate the return of the Roman emperor from Gallia in 9 BC (Fig. 12a). It was built using

Figure 8. Bargiolina Quartzite: a) Quarry site located on Mount Bracco (site 15 in Figure 2); b) macroscopic aspect of the rock, characterized by a natural split surface defined by thin mica layers; c) microscopic aspect (crossed-polarized light), marked by a strong dimensional preferential orientation of quartz crystals.

Foresto and Chianocco Marble, exploited in the immediate area of the Arch; indeed, looking through the Arch it is possible to see the remains of the original quarry. These materials were also employed for part of the Roman aqueduct of Segusium (present-day Susa).

During Medieval times, the most salient heritage building, partly constructed using Dora-Maira stones, was the Sacra di San Michele. It is standing on the peak of Mount Pirchiriano at 962 m a.s.l., near Sant'Ambrogio village, on the southern slope of the Susa Valley (Fig. 12b), and was one of the most important fortified monasteries in southern Europe. Construction of the Sacra di San Michele lasted several centuries and, at present, it stands out against the sky as a huge stone edifice. The first sanctuary probably dates before 1000 AD,

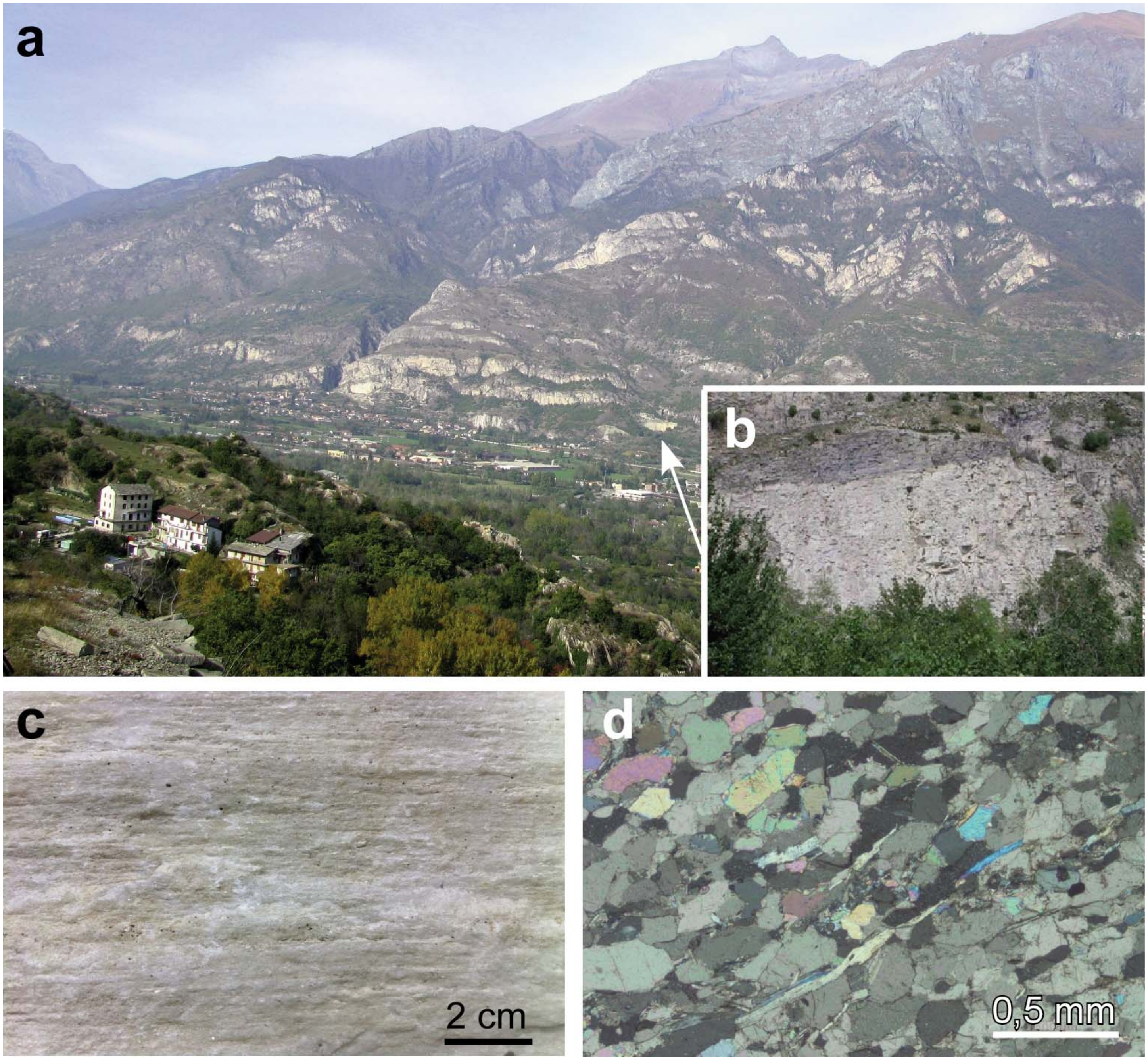


Figure 9. Foresto Marble: a) The northern slope of the lower Susa Valley, where the historic marble quarry b) is located (quarry site 1 in Figure 2); c) macroscopic aspect of the rock, characterized by a natural split surface defined by white mica; d) microscopic aspect (crossed-polarized light), marked by granoblastic texture and oriented lamellae of white mica.

and it was finally completed at the end of 1100 AD. In the 11th century the monastery was enlarged with the construction of the large church, characterized by the Scalone dei Morti (Staircase of the Dead). Because of its strategic position it was an important presidium of the Via Francigena, one of the most ancient communication routes in Europe. Over the centuries, different variety of stones from the Dora-Maira Unit were exploited to build the Sacra di San Michele: Borgone Stone was used for the steps of the Scalone dei Morti; the garnet-bearing micaschists of the polymetamorphic basement are visible at the entrance gate of the Sacra; and the Chianocco and Foresto Marble were used for the construction of the Portal of the Zodiac, a striking expression of Romanesque art of the 12th century (Fig. 12c). The Luserna Stone was used to build the access pathway to the monastery during the recent restoration for the XX Winter Olympic Games.

Dora-Maira stones were also employed in the Fenestrelle Fortress, a group of military buildings and infrastructures built between the 18th and 19th centuries in the Chisone Valley (80 km northeast of Turin) (Fig. 12d). This fortified complex covers an area of 1.3 million m^2 on the northern side of the middle Chisone Valley, between 1150 and 1750 m a.s.l. It consists of three core areas, one beside the other in chronological order: Forte Valli, Forte Tre Denti and Forte San Carlo. The fortress is entirely made of stone: the walls and the blocks constituting the pillars, columns and portals. The Scala Coperta

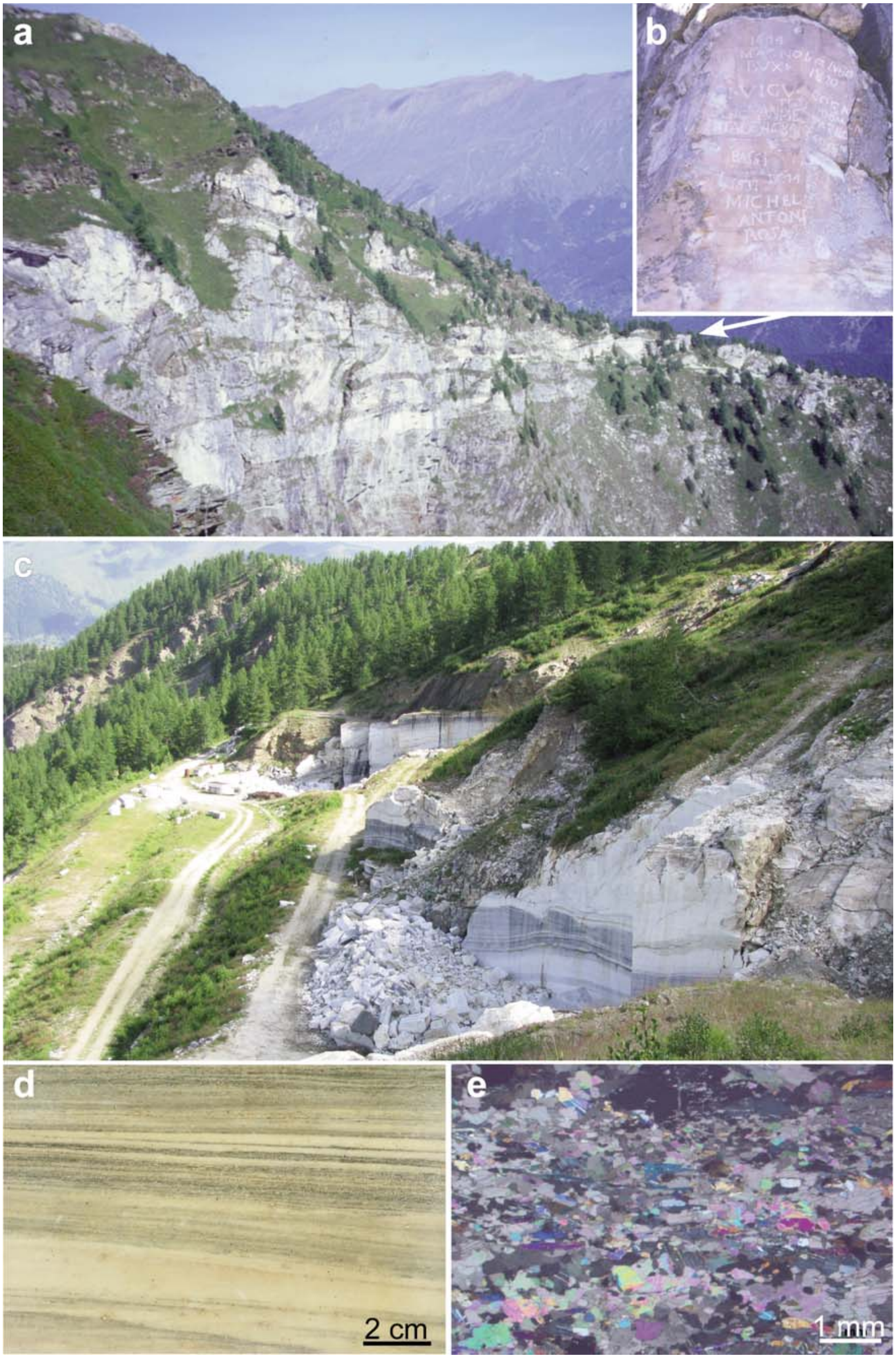


Figure 10. a) The eastern slope of the Rocca Bianca Mount (Germanasca Valley), where traces of the historic quarry of Prali Marble are still visible (quarry site 12 in Figure 2); b) graffiti dating back to the end of 1500 carved on a quarry face; c) Maiera Quarry, located along the western slope of the Rocca Bianca Mount (quarry site 11 in Figure 2), where the marble was exploited as recently as 2005; d) macroscopic aspect of the marble, characterized by regular intercalation of carbonate (light) and phyllosilicate layers; e) microscopic aspect (crossed-polarized light), marked by oriented crystals of tremolite and white mica, which define the anisotropy of the rock. Photo credits a) and b): Alessandro Ghelli and Cadoppi et al. 2008, respectively.

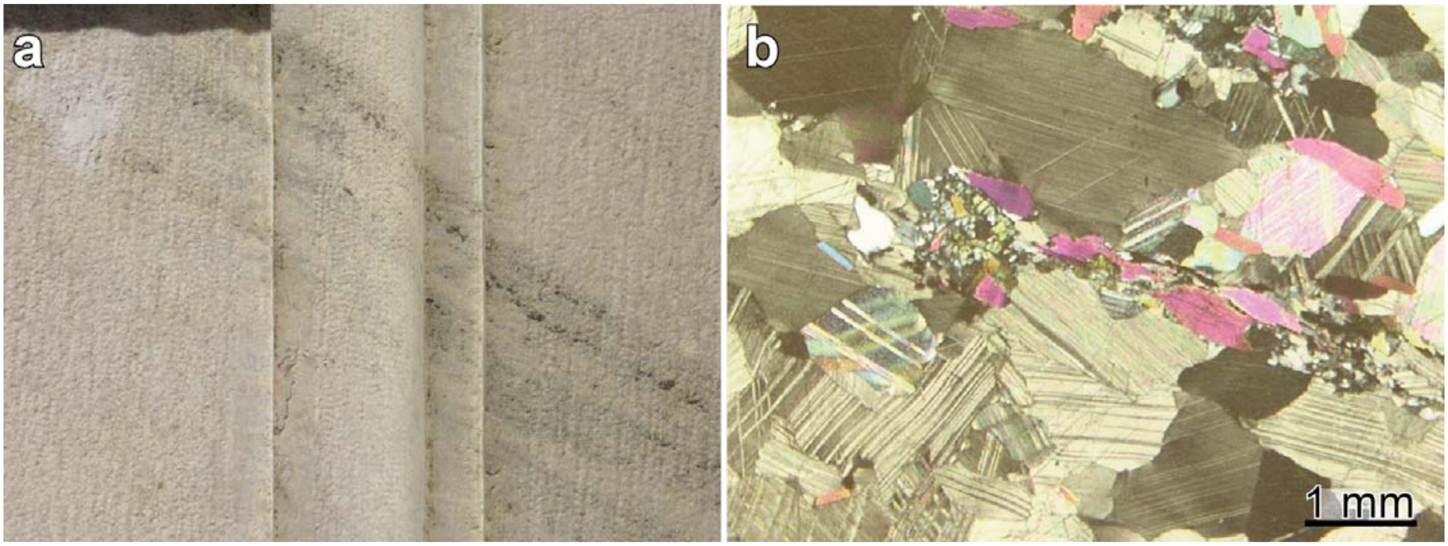


Figure 11. Brossasco Marble: a) Macroscopic aspect of the rock in an architectonical element of the San Filippo Neri Church; b) microscopic aspect (crossed-polarized light), characterized by the coarse and heterogeneous size of the carbonate grains and the occurrence of phlogopite lamellae.

(Covered Staircase) is worthy of note: it is the longest stone staircase in Europe, consisting of 3996 steps. Linking 28 bastions, it looks like a great wall connecting the upper and lower part of the fortress; the first 1250 steps are made of Malanaggio Stone (Fig. 12e) (Fiora et al. 2006). This material was also employed for the plinths of the Porta Reale, which is the ancient entrance to the Forte San Carlo, reserved for personages of the royal courts of Europe who visited the fortress. Luserna Stone and other gneisses extracted in the Chisone and Susa valleys were employed for the roofs of the Governor's Palace, the church of the Forte San Carlo, and the Officers' Palace. Finally, the garnet-bearing micaschist of the polymetamorphic basement was employed in the highest part of the fortress (Forte Valli) and in the last 1046 steps of the Scala Coperta.

Some of the historical stones quarried in the Dora-Maira Unit were also used for the construction of the Exilles Fortress, located in the middle Susa Valley, and dating back to the early 1800s in its present form; the original one was built during the Medieval Period (Fig. 12f). This is a typical example of a building made of stone that crops out on site. The walls consist of blocks of strongly schistose, easily splittable rock types. In particular, Villar Focchiardo Stone was employed for embrasures that overlook the French side, whereas Borgone and Vaie stones were used in the masonry and for the fountain of the main parade ground.

Historic Centre of Turin

Turin can be described as a 'stone city,' because most of the historical buildings, roads and squares are made of stone of local, national and international provenance. In particular, it is possible to appreciate the use of Dora-Maira stones in some interesting and historical buildings, such as the Gran Madre church, San Giovanni Cathedral, Palazzo Madama, the Royal Palace and Mole Antonelliana, along with infrastructure such as stone bridges. San Giovanni Cathedral (Turin cathedral) is the only Renaissance building still preserved in the city (Fig. 13a). Its façade is made of Foresto and Chianocco Marble. The marble blocks are creamy white to light grey and have a metamorphic foliation defined by centimetre-thick layers of varying colour. These blocks, randomly placed on the façade of the Dome, produce a 'checkerboard effect,' which was popular at the time. Foresto and Chianocco Marble were preferred to other contemporarily exploited materials because the blocks were easily transported from quarries to the cathedral yard by means of barges along Dora Riparia River. Stones from the Dora-Maira Unit were widely employed during the time of the Savoy kingdom. One of the most representative heritage buildings from this period is the Royal Palace, where there is a great deal of Malanaggio Stone and Prali Marble used for the inner court and gate pillars, respectively.

Chianocco and Foresto Marble have also been employed for columns of the façade of Palazzo Madama (1718–1721) (Fig. 13b), which hosted the Senate of the royal house during the Savoy period and where the Albertine Statute, progenitor of the Italian constitution, was approved. Here, it is also possible to appreciate several kinds of stones from the Dora-Maira Unit, including Prali Marble, used for capitals and bases of the columns of the façade; Brossasco Marble, for statues and vases that sit on the top of the façade; and Vaie Stone, used for the basement.

Vaie Stone was employed for construction of the columns of the 18th century façade of Santa Cristina Church (Piazza San Carlo; Fig. 13c), designed by Filippo Juvarra (one of the main architects at the Savoy court). Also used for the capitals and portal of the façade were Perosa Stone and Chianocco and Foresto Marble. Dora-Maira stones were also utilized in two other important churches in Turin: San Filippo Neri Church (1650–1891) and Gran Madre Church (early 19th century), both characterized by typical neo-classical elements such as the *pronao* (colonnade entrance). In particular, in the San Filippo Neri Church, the largest religious building in Turin (Fig. 13d), the atrium is made of Bargiolina Quartzite and the eight grooved columns consist of Brossasco White Marble. Malanaggio Stone and Prali Marble are present in the Gran Madre Church (Fig. 13e), the former for the columns and the latter for the sculptures and statues at the entrance of the church.

Figure 12. Main examples of employment of Dora-Maira dimension stones in historic buildings: a) Arc of Augustus at Susa (Roman Age, 9 BC); b) Sacra di San Michele Abbey located at the mouth of the Susa Valley; c) 'Portale dello Zodiaco,' one of the great expressions of Romanesque art of the 12th century; d) external features of the Scala Coperta of the Fenestrelle Fortress along the northern slope of the Chisone Valley; e) steps and internal appearance of the Scala Coperta; f) Exilles Fortress located along the Susa Valley.

Last, Luserna Stone was employed in the Mole Antonelliana (1863–1904), particularly in the slabs covering the dome (Fig. 13f). This was the tallest masonry building in the world when it was inaugurated in 1889.

Other important civil infrastructures were made of Dora-Maira stones: e.g. the six stone bridges over the Po River in Turin, three of which are entirely made of stone: King Vittorio Emanuele I Bridge (1803–1813), Princess Isabella Bridge (1876–1880) and King Umberto I Bridge (1903–1907) (Fig. 14). King Vittorio Emanuele I Bridge is the tangible sign of the acme of Napoleonic power; the architecture is of high quality and it stands as a prototype for the resurgence of stone building in Piedmont. Furthermore, it represents the first modern stone bridge built in Italy after the Renaissance, and thus has an important historical role. The exclusive use of Cumiana Stone for the construction of the bridge is documented at Turin State Archives; Cumiana Stone was preferred to the others because of its characteristics and the short distance between the quarry and bridge yard. Cumiana Stone was also employed in the slabs of the sidewalk (now replaced), and

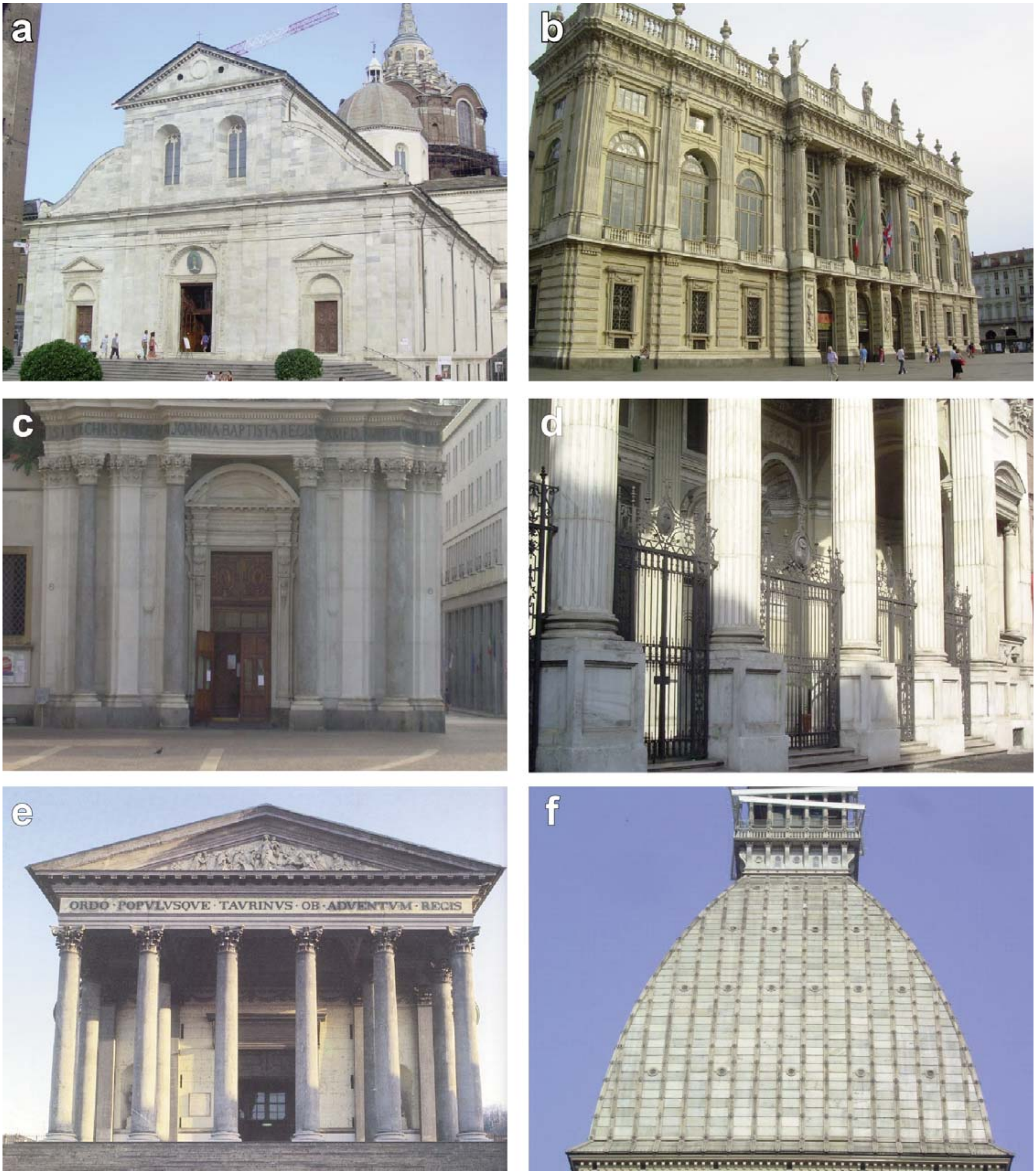


Figure 13. Representative examples of historic buildings in Turin, mainly made of Dora-Maira dimension stones: a) Façade of San Giovanni Battista Church, made of Chianocco and Foresto Marble; b) façade of Palazzo Madama, seat of the Savoy Senate, made with Chianocco and Foresto Marble and the Vaie Stone; c) façade of Santa Cristina Church, with columns made of Vaie Stone; d) San Filippo Neri Church, with the colonnade built of Brossasco Marble; e) colonnade of the Gran Madre Church made of Malanaggio Stone; f) Mole Antonelliana, symbol of the city of Turin, built in the late 19th century with material from the Alpine valleys. The dome is covered by the Luserna Stones slabs.

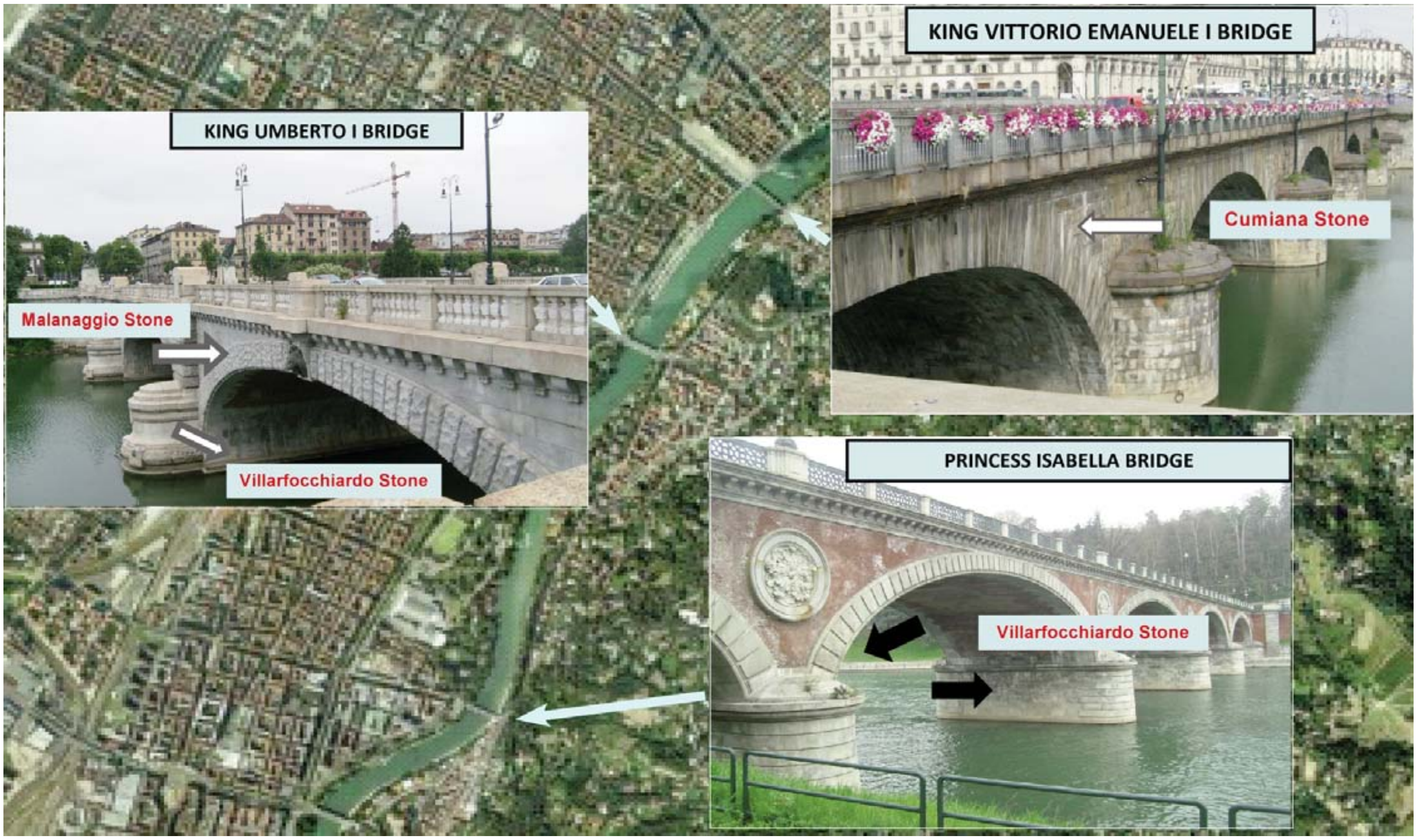


Figure 14. Satellite map of Turin (from Google Earth®, 22/03/2015), showing the location of the Po River bridges built with Dora-Maira stones.

in the wedges of the archways. The original railings were made of Malanaggio Stone, but in 1876 they were removed and replaced by cast iron railings.

Princess Isabella Bridge was built between 1876 and 1880; it has 24 metres of span and five semi-elliptical arches entirely made of brick and resting on tall pillars of Villar Focchiardo Stone. The paving consists of slabs of Luserna Stone confined by curbs of Villar Focchiardo Stone. The newer King Umberto I Bridge (1903–1907) is made of bricks as well as stone. It has three semi-elliptical arches on pillars, each characterized by a semi-circular rostrum. Several kinds of Dora-Maira stones, including Malanaggio, Villar Focchiardo and Vaie stones, were employed. The coating of the pillars is made of Villar Focchiardo Stone, whereas the part of the structure in plain sight, including the arches, is coated by Malanaggio Stone, worked with various techniques (Fig. 14).

Dora-Maira stones can be seen in two comparatively modern components of Turin's infrastructure: the Automobile Museum and the Metro stations. Both Luserna Stone and Perosa Stone have been used for the recently restored outer coating of the Automobile Museum.

The international application of Dora-Maira stones is noteworthy. For example, Borgone and Vaie stones have been used for the paving of the Louvre Museum, and Perosa Stone was employed in Lagos for the Monument of Independence.

CONCLUSIONS

Ornamental and dimension stones extracted from the Dora-Maira Unit have been used for important buildings from Roman times up to the present day. In the 16th and 17th centuries, with the establishment of the kingdom of Savoy, stone was widely employed in Turin, the capital. From the second half of the 19th century to contemporary times, these ornamental stones continued to be employed in public buildings, including the Mole Antonelliana, which is the major landmark building in Turin, and other important infrastructural elements such as the stone bridges over the Po River. Some of these stones are still quarried and exported to foreign countries, such as the Luserna Stone, San Basilio Stone, Perosa Stone and the Bargiolina Quartzite.

The Dora-Maira Unit is almost unique in the number and variety of ornamental and building stones exploited over the centuries from a relatively small area. For this reason, it can be considered a Global Heritage Stone Province. Moreover, active and historical quarries that occur in this geological unit are interesting sites in terms of geo-tourism. The quarries can also be used to stage cultural events such as concerts and plays. In turn, this can introduce the general public to quarries as a vital industrial activity in contrast to the negative way in which they are often portrayed (Dino and Cavallo 2015). For example, cultural events staged in locales of past mining activity, such as those hosted in abandoned galleries of the talc mine in Germanasca Valley (Scopri Miniera and Scopri Alpi; www.scopriminiera.it), could be extended to other quarries in the Dora-Maira region (e.g. Luserna Stone quarries).

ACKNOWLEDGEMENTS

This research has been funded by Compagnia San Paolo and University of Turin within the ProGeoPiemonte Project and University of Turin Grants (ex-60%; responsible Festa A.). Franco Ajmone Marsan and Brian Pratt are thanked for the revision of the text.

REFERENCES

Avigad, D., Chopin, C., and Le Bayon, R., 2003, Thrusting and extension in the southern Dora-Maira ultra-high-pressure massif (Western Alps): View from below the coesite-bearing unit: The Journal of Geology, v. 111, p. 57–70, http://dx.doi.org/10.1086/344664.

Balestro, G., Cadoppi, P., Di Martino, L., and Sacchi, R., 1995, Il settore meridionale del Massiccio Dora-Maira (Valli Maira e Varaita): inquadramento, carta geologica e guida a un'escursione, *in* Polino, R., and Sacchi, R., *eds.*, Proceedings of "Convegno Rapporti Alpi-Appennini," 31/5–1/6/1994, Peveragno (CN): Accademia Nazionale delle Scienze, Scritti e Documenti, v. 14, p. 501–529.

Barisone, G., Bottino, G., Coda, D., and Fornaro, M., 1992, Potenzialità di ripresa produttiva, in un'ottica di pianificazione territoriale, di cave di pietre ornamentali in Val Susa: Atti 1° Conferenza Europea sulle Cave, EUROCAVE '92, Saint Vincent (AO), 6-8 ottobre 1992, PEI Ed., Parma, p. 28–31.

Borghi, A., Cadoppi, P., Porro, A., Sacchi, R., and Sandrone, R., 1984, Osservazioni geologiche nella Val Germanasca e nella media Val Chisone (Alpi Cozie): Bollettino del Museo Regionale di Scienze Naturali, Torino, v. 2, p. 503–530.

Borghi, A., Cadoppi, P., Porro, A., and Sacchi, R., 1985, Metamorphism in the northern part of the Dora Maira Massif (Cottian Alps): Bollettino del Museo Regionale di Scienze Naturali, Torino, v. 3, p. 369–380.

Borghi, A., Compagnoni, R., and Sandrone, R., 1996, Composite *P–T* paths in the Internal Penninic Massifs of the Western Alps: Petrological constraints to their thermo-mechanical evolution: Eclogae Geologicae Helvetiae, v. 89, p. 345–367.

Borghi, A., D'atri, A., Martire, L., Castelli, D., Costa, E., Dino, G., Favero Longo, S.E., Ferrando, S., Gallo, L.M., Giardino, M., Groppo, C., Piervittori, R., Rolfo, F., Rossetti, P., and Vaggelli, G., 2014, Fragments of the Western Alpine chain as historic ornamental stones in Turin (Italy): Enhancement of urban geological heritage through Geotourism: Geoheritage, v. 6, p. 41–55, http://dx.doi.org/10.1007/s12371-013-0091-7.

Borghi, A., Berra, V., D'atri, A., Dino, G.A., Gallo, L.M., Giacobino, E., Martire, L., Massaro, G., Vaggelli, G., Bertok, C., Castelli, D., Costa, E., Ferrando, S., Groppo, C., and Rolfo, F., 2015, Stone materials used for monumental buildings in the historical centre of Turin (NW Italy): architectonical survey and petrographic characterization of Via Roma, *in* Pereira, D., Marker, B.R., Kramar, S., Cooper, B.J., and Schouenborg, B.E., *eds.*, Global Heritage Stone: Towards International Recognition of Building and Ornamental Stones: Geological Society, London, Special Publications, v. 407, p. 201–218, http://dx.doi.org/10.1144/SP407.20.

Bussy, F., and Cadoppi, P., 1996, U–Pb zircon dating of granitoids from the Dora-Maira massif (western Italian Alps): Schweizerische Mineralogische Petrographische Mitteilungen, v. 76, p. 217–233.

Cadoppi, P., 1990, Geologia del basamento cristallino nel settore settentrionale del Massiccio Dora-Maira (Alpi Occidentali): Unpublished PhD thesis, University of Turin, Italy, 208 p.

Cadoppi, P., and Tallone, S., 1992, Structural and lithostratigraphic heterogeneity of the northern part of Dora-Maira massif (Western Alps): Atti Ticinensi di Scienze della Terra, v. 35, p. 9–18.

Cadoppi, P., Castelletto, M., Sacchi, R., Baggio, P., Carraro, F., and Giraud, V., 2002, Explanatory notes, Susa—154 sheet, Geological Map of Italy, 1:50,000 scale: APAT, Rome, Italy, 123 p.

Cadoppi, P., Ghelli, A., and Tallone, S., 2008, Il marmo di Rocca Bianca (Val Germanasca, Alpi Occidentali), *in* Baldassarre, G., and Giuliani, A., *eds.*, Addendum to proceedings of the Congress "Le risorse lapidee dall'antichità ad oggi in area mediterranea," Canosa di Puglia (Bari), 25–27 September 2006: GEAM Associazione Georisorse e Ambiente, Turin, p. 25–30.

Carraro, F., Cadoppi, P., Baggio, P., Bellino, L., Castelletto, M., Giraud, V., and Mensio, L., 2002, Susa–154 sheet, Geological Map of Italy, 1:50,000 scale: APAT, Rome, Italy.

Chopin, C., 1984, Coesite and pure pyrope in high-grade blueschists of the Western Alps: a first record and some consequences: Contributions to Mineralogy and Petrology, v. 86, p. 107–118, http://dx.doi.org/10.1007/BF00381838.

Chopin, C., Henry, C., and Michard, A., 1991, Geology and petrology of the coesite-bearing terrain, Dora Maira massif, Western Alps: European Journal of Mineralogy, v. 3, p. 263–292, http://dx.doi.org/10.1127/ejm/3/2/0263.

Compagnoni, R., 2003, HP metamorphic belt of the Western Alps: Episodes, v. 26, p. 200–204.

Compagnoni, R., Hirajima, T., and Turello, R., 1993, L'unita` a coesite di Brossasco-Isasca, Massiccio Dora-Maira meridionale, Alpi Occidentali: 60° Congresso SIMP, Torino, Guida all'escursione: Plinius, v. 10, p. 275–293.

Compagnoni, R., Rolfo, F., Groppo, C., Hirajima, T., and Turello, R., 2004, Mapping of Alpine rocks characterized by "HP" to "UHP" metamorphic overprint in the Southern Dora-Maira Massif (Western Alps), *in* Pasquarè, G., Venturini C., and Groppelli, G., *eds.*, Mapping Geology in Italy: APAT- Dipartimento Difesa del Suolo – Servizio Geologico d'Italia, Roma, v. 34, p. 287–294.

Compagnoni, R., Rolfo, F., Groppo, C., Hirajima, T., and Turello, R., 2012, Geological map of the ultra-high pressure Brossasco-Isasca unit (Western Alps, Italy): Journal of Maps, v. 8, p. 465–472, http://dx.doi.org/10.1080/17445647.2012.744367.

Cooper, B.J., 2015, The 'Global Heritage Stone Resource' designation: past, present and future, *in* Pereira, D., Marker, B.R., Kramar, S., Cooper, B.J., and Schouenborg, B.E., *eds.*, Global Heritage Stone: Towards International Recognition of Building and Ornamental Stones: Geological Society, London, Special Publications, v. 407, p. 11–20, http://dx.doi.org/10.1144/SP407.5.

Dal Piaz, G.V., Bistacchi, A., and Massironi, M., 2003, Geological outline of the Alps: Episodes, v. 26, p. 175–180.

Dino, G.A., and Cavallo, A., 2015, Ornamental stones of the Verbano Cusio Ossola quarry district: characterization of materials, quarrying techniques and history and relevance to local and national heritage, *in* Pereira, D., Marker, B.R., Kramar, S., Cooper, B.J., and Schouenborg, B.E., *eds.*, Global Heritage Stone: Towards International Recognition of Building and Ornamental Stones: Geological Society, London, Special Publications, v. 407, p. 187–200, http://dx.doi.org/10.1144/sp407.15.

Dino, G., Fornaro, M., Martinetto, V., Rodeghiero, F., and Sandrone, R., 2001, Le risorse estrattive del Monte Bracco: valorizzazione mineraria e recupero ambientale: Geoingegneria Ambientale e Mineraria, v. 104, p. 195–202.

Fiora, L., and Audagnotti, S., 2001, Il Marmo di Chianocco e Foresto: caratterizzazione minero–petrografica ed utilizzi, *in* Martini, M., *ed.*, Atti 1° congresso nazionale di archeometria: Verona, 2–4 dicembre 1999, Patron Editore, p. 235–246.

Fiora, L., and Gambelli, E., 2003, Pietre naturali in Val di Susa (Parte Seconda): Marmor, v. 81, p. 37–50.

Fiora, L., Alciati, L., Costa, E., Rolfo, R., and Sandrone, R., 2002, La bargiolina: pietra storica piemontese: L'informatore del marmista, v. 486, p. 6–16.

Fiora, L., Borghi, A., Canalis, T.R., and Sandrone, R., 2006, I materiali lapidei del Forte di Fenestrelle (Val Chisone, Piemonte), *in* Crisci, G.M., and Gattuso, C., *eds.*, Archeometria del costruito: Edipuglia, p. 147–155.

Fusetti, E., Perrone, G., Morelli, M., and Cadoppi, P., 2012, Analysis of the fault pattern in the Lower Lanzo Valley (Italian Western Alps): a multi-scale integrated approach: Italian Journal of Geosciences, v. 131, p. 286–301.

Gasco, I., Gattiglio, M., and Borghi, A., 2011, Lithostratigraphic setting and *P–T* metamorphic evolution for the Dora Maira Massif along the Piedmont Zone boundary (middle Susa Valley, NW Alps): International Journal of Earth Sciences, v. 100, p. 1065–1085, http://dx.doi.org/10.1007/s00531-011-0640-8.

Gebauer, D., Schertl, H.-P., Brix, M., and Schreyer, W., 1997, 35 Ma old ultrahigh-pressure metamorphism and evidence for very rapid exhumation in the Dora Maira Massif, Western Alps: Lithos, v. 41, p. 5–24, http://dx.doi.org/10.1016/S0024-4937(97)82002-6.

Henry, C., Michard, A., and Chopin, C., 1993, Geometry and structural evolution of ultra-high-pressure and high-pressure rocks from the Dora-Maira massif, Western Alps, Italy: Journal of Structural Geology, v. 15, p. 965–981, http://dx.doi.org/10.1016/0191-8141(93)90170-F.

Kienast, J.R., Lombardo, B., Biino, G., and Pinardon, J.L., 1991, Petrology of very-high-pressure eclogitic rocks from the Brossasco–Isasca Complex, Dora–Maira Massif, Italian Western Alps: Journal of Metamorphic Geology, v. 9, p. 19–34, http://dx.doi.org/10.1111/j.1525-1314.1991.tb00502.x.

Marengo, A., Borghi, A., Cadoppi, P., and Costa, E., 2014, The Busca Onyx: an historical ornamental stone from Piedmont, *in* Silvertant, J., *ed.*, Research and preservation of ancient mining area: 9th International symposium on archaeological mining history, Trento, Italy, IES Yearbook, p. 289–299.

Marker, B.R., 2015, Procedures and criteria for the definition of Global Heritage Stone Resources, *in* Pereira, D., Marker, B.R., Kramar, S., Cooper, B.J., and Schouenborg, B.E., *eds.*, Global Heritage Stone: Towards International Recognition of Building and Ornamental Stones: Geological Society, London, Special Publications, v. 407, p. 5–10, http://dx.doi.org/10.1144/sp407.3.

Peretti, L., 1938, Rocce del Piemonte usate come pietre da taglio e da decorazione: Marmi, Pietre e Graniti, v. 16, p. 1–43.

Pognante, U., and Sandrone, R., 1989, Eclogites in the Northern Dora–Maira Nappe (Western Alps, Italy): Mineralogy and Petrology, v. 40, p. 57–71, http://dx.doi.org/10.1007/BF01162469.

Sandrone, R., Cadoppi, P., Sacchi, R., and Vialon, P., 1993, The Dora–Maira Massif, *in* von Raumer, J.F., and Neubauer, F., *eds.*, Pre-Mesozoic Geology in the Alps: Springer, Berlin, p. 317–325.

Sandrone, R., Alciati, L., De Rossi, A., Fiora, L., and Radicci, M.T., 2000, Estrazione, lavorazione ed impieghi della Pietra di Luserna, *in* Riganti, V., and Braga, G., *eds.*, Quarry-Laboratory–Monument International Congress Proceedings, Pavia, 26–30 settembre 2000, v. 2, p. 41–49.

Sandrone, R., Colombo, A., Fiora, L., Lovera, E., Tunesi, A., and Cavallo, A., 2004, Contemporary natural stones from the Italian western Alps (Piedmont and Aosta Valley Regions): Periodico di Mineralogia, v. 73, p. 211–226.

Schmid, S.M., Fügenschuh, B., Kissling, E., and Schuster, R., 2004, Tectonic map and overall architecture of the Alpine orogen: Eclogae Geologicae Helvetiae, v. 97, p. 93–117, http://dx.doi.org/10.1007/s00015-004-1113-x.

Vialon, P., 1966, Etude géologique du massif cristallin Dora Maira, Alpes cottiennes internes, Italie: Thèse d'état, Université de Grenoble, Grenoble, 293 p.

Wheeler, J., 1991, Structural evolution of a subducted continental sliver: the northern Dora Maira massif, Italian Alps: Journal of the Geological Society, v. 148, p. 1101–1113, http://dx.doi.org/10.1144/gsjgs.148.6.1101.

Received October 2015
Accepted October 2015
First published on the web January 2016