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Gneisses (*Serizzo* and *Beola*) of the Verbano-Cusio-Ossola district (Piedmont, Northern Italy): possible candidates for the designation as a Global Heritage Stone Province

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Abstract: The Verbano-Cusio-Ossola quarrying district (Piedmont, northern Italy) produces many different ornamental stones (granites, gneisses, marbles); two important categories are represented by *Serizzo* and *Beola* gneisses. The *Serizzo*, a group of foliated orthogneisses, is the most important and extensively exploited ornamental stone, largely used to produce columns since the end of XV century, and was used for many parts of the Duomo di Milano. *Beola* is the name of a group of heterogeneous orthogneisses with mylonitic foliation and strong mineralogical lineation, easy to split into thin slabs with hammer and chisel, occurring in the middle Ossola Valley. The quarries of *Beola* are probably the oldest of the Ossola Valley (since Roman period), and the *Beola* trade probably started at the end of the XIII century. In general, *Beola and Serizzo* gneisses have been used for ornamental purposes and for the construction of churches, palaces and monuments, widely documented in many towns and villages of the Ossola Valley and in northern Italy. This contribution reviews the history and distinctiveness of these materials, their importance in local and national culture, and their present international diffusion. Both stones are recommended as a Global Heritage Stone Resource in a Global Heritage Stone Province.

Quarrying activity in the Verbano Cusio Ossola province (VCO, Piedmont, Northern Italy) occurs in the area between the Cusio and Verbano lakes in the northern Ossola valleys, close to the border with Switzerland. It is a very peculiar quarrying district in Italy, because it represents a natural "geological section" through the Alpine chain (**Fig. 1**), including a huge variety of extractable rocks, ranging from granites, marbles, gneisses to soapstones and granulites. Even similar lithologies, especially gneisses and marbles, exhibit different colours and textures, due to different deformation and metamorphic events. The most important and extensively exploited materials are represented by *Serizzo* and *Beola*, a heterogeneous group of orthogneisses, with relatively similar mineralogical composition, but different textures and microstructures, ranging from gneissic (*Serizzo*) to mylonitic (*Beola*). The *Serizzo* varieties, by far the most common commercial rock types, are quarried in the northern part of the VCO district (comprising about 70% of all the dimension stones in the district), while the *Beola* varieties derive from the middle Ossola valley. The former are relatively coarse grained and mildly schistose, whereas the latter are fine grained and extremely foliated, perfect for splitting in thin slabs. The historical uses of these materials are extremely varied, ranging from rural (e.g. roof covering) and structural uses (load-bearing elements) to artistic uses (statues, columns, etc.). Ample availability and easy workability, related to the pervasive foliation, as well as excellent durability, has resulted in extensive use of these materials, beginning in Roman times. This article outlines the characteristics of these stones that recommend them as potential Global Heritage Stone Resources within a potential Global Heritage Stone Province.

Geological setting

Due to the complex geology of the VCO, detailed structural and petrographical descriptions are provided below for the description and distinction of these lithotypes. The VCO is located in the Alpine chain, a composite double-verging belt derived from continent-continent collision between the Europe and Adria (Africa) plates during Alpine orogenesis. The thickest geological section (approximately 20 km) of the Alpine belt can be observed in the Central Alps, mainly in the Ossola Valley. From South to North, there are two main structural domains (**Fig. 1**), separated by the Periadriatic lineament (Schmid et *al*., 1987; Boriani, 2000; Cavallo *et al*., 2004a; Colombo & Cavallo, 2007): the pre-alpine basement of the Southern Alps, and the Alpine nappe systems (Austroalpine and Penninic domains, separated by the Antrona and Zermatt-Saas ophiolites). The Southern Alps are mainly represented by basement rocks that are part of the European Hercynian Belt, whereas the Alpine nappe system consists of minor Permo-Mesozoic cover rocks and prevailing pre-Alpine crystalline basement rocks, intruded by late-Variscan gabbro and granitoid plutons. The Southern Alps are represented in the VCO area by the Serie dei Laghi (upper continental crust) and the Ivrea-Verbano Zone (lower continental crust), divided by the subvertical Cossato-Mergozzo-Brissago Line. The Serie dei Laghi comprises the metasedimentary Scisti dei Laghi and the Strona-Ceneri Zone units, and the contact is represented by lenses of mafic and ultramafic rocks (Strona Ceneri Border Zone). Large lens-shaped bodies of Ordovician metagranitoids (450-460 Ma) are mainly located near Strona Ceneri Border Zone. The main metamorphic imprint of the "Serie dei Laghi" occurred under amphibolite facies conditions (early Palaeozoic or Hercynian), with estimated PT conditions of 6-9 kbar and 540-610 °C (Colombo & Tunesi, 1999; Boriani & Giobbi, 2004). Late Variscan granites (Graniti dei Laghi (extensively quarried in the past, especially the pink *Rosa Baveno*), the white *Bianco Montorfano* and the green *Verde Mergozzo* varieties) intrude this basement, and dikes or stocks of the Appinite suite (275-285 Ma) occur along the Cossato-Mergozzo-Brissago Line. The Ivrea-Verbano Zone consists of two main units: the Kinzigite Formation, a volcano-sedimentary sequence with lenses of marbles (e.g. Candoglia and Ornavasso calcitic marbles) and ultramafic tectonites; and the Mafic Complex, composed of an early-Permian a layered sequence (peridotites, pyroxenites, gabbro-norites and anorthosites) and a huge body of amphibole-bearing gabbro (Main Gabbro). The Kinzigite Formation suffered upper-amphibolite to granulite facies conditions, and the age of metamorphism is between 273-296 Ma, whereas the Mafic Complex shows granulite facies assemblages (no greater than 10-12 kbar and 850 ± 100 °C, Boriani & Giobbi, 2004). The present subvertical tectonic setting is interpreted as an early Permian trans-tensional emplacement of the Ivrea-Verbano Zone near to the Serie dei Laghi across the Cossato-Mergozzo-Brissago Line.

The Alpine nappe system occurs from the middle Ossola Valley up to Switzerland across the national borders (**Fig. 1**). Strong Alpine metamorphic overprinting mainly occurred under amphibolite facies conditions; relicts of the pre-alpine or eo-alpine history are scarce and mainly recognized in the

Austroalpine units, Piemontese Zone and Upper Penninic nappes (Monte Rosa). In the medium Ossola Valley the nappe systems form part of the southern steep belt: the structural attitude is sub-vertical or north-dipping, due to the back-thrust over the rocks of the Ivrea-Verbano Zone during the late alpine events. The most significant alpine deformation phases occurred can be summarized as follows (Keller *et al.*, 2005; Maxelon & Macktelow, 2005): the first phases (D1 and D2) are linked to the "nappe piling" (Eocene, 51-44 Ma), and they started under the HP-HT conditions (12.5–16 kbar; 620–700 °C), whereas the later phases of deformation (D3 and D4, Eocene – Oligocene, 37 – 26 Ma) are due to the backthrusting - backfolding phase, related to the exhumation process and are linked to a dextral transpressive orogen-parallel component. D4 became active during the end of D3 (at about 27 Ma) and continued up to 10 Ma.

In the Ossola Valley from the SE to the NW the following nappe systems are recognizable:

(a) Fobello-Rimella Schists, a thick shear zone (1-2 km) consisting mainly of mylonitic orthogneisses and paragneisses in greenschist facies, occurring in the inner border of the Sesia-Lanzo Zone, close to the Insubric Line (Schmid *et al.*, 1987). Some varieties of the quarried *Beola* from the Vogogna area (*Verde Vogogna* and *Quarzite Bianca*) belong to this unit.

(b) Sesia-Lanzo Zone (Austroalpine domain), represented by paragneisses with minor orthogneisses and metabasites (late-Variscan protoliths), which suffered eo-alpine metamorphism under eclogitic - blueschist facies and meso-alpine metamorphism under greenschist facies.

(c) Piedmont-Ligurian basin (ophiolitic units) represented in the Ossola Valley by the Combin unit (calcschists and metabasites under transitional blueschist/greenschist facies conditions) and Zermatt-Saas Zone (prevailing mafic and ultramafic rocks under eclogitic facies with a later greenschist -amphibolitic facies overprint).

(d) Upper Penninic units, represented by the Monte Rosa Zone, the Camughera/Moncucco-Orselina-Isorno Zone and the San Bernardo nappe units (Engi et al., 2001; Maxelon & Mancktelow, 2005; Pleuger et al., 2007); the former two units are separated by the Antrona Zone (an ophiolitic unit, mainly composed of mafic and ultramafic rocks). The Monte Rosa nappe (Upper Penninic domain) is part of the palaeo-Europe continental margin of the Tethys ocean, and is composed of a pre-alpine metamorphic basement and a huge mass of Variscan meta-granitoids (310 and 270 Ma), under amphibolitic facies conditions. Many varieties of *Beola* belong to this unit. The Camughera unit is very similar to the Monte Rosa Zone regarding rock types and tectonic evolution, whereas the Moncucco-Orselina-Isorno Zone consists of prevailing metasediments with minor orthogneisses (late-Variscan granites, now quarried as *Beola*) and metabasites. The San Bernardo nappe mainly includes the Siviez-Mischabel nappe (mainly paragneisses), the Zone Houillère and the Pontis nappe (metapelites and minor orthogneisses).

(e) Lower Penninic units, cropping out in the northern Ossola Valley (sub-vertical attitude to the South and sub-horizontal towards North): from top to bottom, the Monte Leone, Lebendun and Antigorio nappe units; the deepest element is the Verampio metagranite. The Monte Leone and Antigorio units are constituted by prevailing orthogneisses (pre-alpine granitoids, quarried as *Beola* and *Serizzo*); the Monte Leone also includes paragneisses and the mafic-ultramafic Cervandone-Geisspfad complex. The Lebendun nappe (Permo-Carboniferous) consists of metasedimentary rocks, whereas the underlaying Antigorio nappe is formed by a huge sub-horizontal (1000 meters thick) body of Variscan orthogneisses (quarried as *Serizzo*). The deepest sub-Penninic unit is the Verampio metagranite (Permian protolith), mantled by the Baceno Schists (metapelites).

Petrographic and technical characteristics

Serizzo and *Beola*, from a geological and petrographical point of view, are foliated (and sometimes lineated) orthogneisses, mainly with granitic to granodioritic protolith, deriving from different tectonic units, reflecting the complex structural and metamorphic evolution of the alpine nappes. Their mineralogical composition is relatively homogeneous (quartz, plagioclase, K-feldspar, biotite, and white mica), but the main difference between *Serizzo* and *Beola* is in fabric and microstructure: *Serizzo* is moderately foliated, with gneissic to augen texture, whereas the *Beola* varieties are characterized by strong mylonitic foliation (thus easily splittable in thin slabs). Basic minero-petrographic characterization of these stones is described below, based on polarized light optical microscopy (PLOM, Leica DME 13595 microscope) on thin sections, quantitative X-ray powder diffraction (XRPD, PANalytical X'Pert PRO PW3040/60 diffractometer) and scanning electron microscopy (SEM, Vega TS Tescan 5163 XM); mineral chemistry was assessed by EDS microprobe (EDAX Genesis 400).

Serizzo is commercialized in four varieties (**Fig. 2**): *Serizzo Antigorio*, *Serizzo Formazza*, *Serizzo Sempione*, and *Serizzo Monte Rosa*.

The first three types derive from the Antigorio nappe, whereas the last one from the Monte Rosa Zone. The quarries are mostly concentrated in the Antigorio and Formazza valleys (Fig. 1), where the Antigorio nappe exhibits a sub-horizontal attitude and reaches its greatest thickness (1000 m). The protolith of the *Serizzo* is a Permian granitoid, with a homogeneous composition, peraluminous character and calcalkaline affinity, metamorphosed during the alpine events (Cavallo *et al*., 2004a). The mineralogical composition is: quartz, K-feldspar (microcline and/or orthoclase, up to 2 cm size, Fig. 4), plagioclase (oligoclase, An 25-30%), biotite, white mica (variable content), and traces of chlorite and allanite. It has medium grainsize, marked planar foliation and augen-gneissic texture, sometimes with mineralogical lineation and iso-orientation of the feldspar aggregates. *Serizzo Antigorio* (the most abundant of these stones) is the darkest variety, due to higher biotite content and finer grain-size than the *Serizzo Formazza*. The *Serizzo Sempione*, occurring in the southern vertically oriented part of the body, shows more gneissic texture and a fine grain size, as a result of a stronger degree of alpine ductile deformation. The *Serizzo Monte Rosa* (Monte Rosa nappe, upper Penninic) is extracted in Anzasca Valley (Ceppo Morelli); it is a coarse grained leucocratic augen gneiss, with coarse K-feldspar porphyroclasts (3-4 cm) surrounded by discontinuous layers of biotite, with irregularly distributed foliation planes.

The other important ornamental stone of the VCO district is the *Beola*, a series of heterogeneous stone materials (Fig. 3) with marked foliation and strong mineralogical lineation, occurring in the medium Ossola Valley between Vogogna and Montecrestese (Fig. 1). The *Beola* derives from different geological units, from South to North:

(a) Fobello-Rimella Schists (*Verde Vogogna* and *Quarzite Bianca* varieties): probably the most peculiar Beola varieties, with marked mylonitic foliation (up to ultramylonites) and the finest grain size. The *Quarzite Bianca* is a leucocratic mylonitic orthogneiss, with abundant white mica and chlorite, whereas the *Verde Vogogna* is a mylonitic metabasite (Ab + Chl + Ep ± Tr-Act).

(b) Monte Rosa nappe (*Bianca*, *Grigia*, *Ghiandonata* and *Striata* varieties): fine-grained orthogneisses characterized by a strong mineralogical lineation mainly due to white mica and tourmaline alignments. Biotite is rare and K-feldspar is porphyroclastic (sometimes poikiloblastic, Fig. 4). Chlorite and Ep are rare and localized in small shear zones. The *Beola Ghiandonata* has the largest K-feldspar porphyroclasts and the most pronounced augen texture, whereas the *Beola Bianca*, the most leucocratic variety (and the highest quartz + feldspars content), has the finest grain size.
(c) Orselina-Moncucco-Isorno zone (*Grigia* and *Grigia Grossolana* varieties): medium to fine grain sized orthogneisses, with biotite and white mica in the same proportion. A mineralogical lineation is present, but less pronounced than in the varieties of the Monte Rosa nappe. Polycrystalline layers of quartz and feldspars are common and are usually parallel to the main foliation; chlorite and epidote are more abundant.
(d) Monte Leone nappe (*Favalle*, *Isorno* and *Argentea* varieties): homogeneous fine grain size and a slight mineralogical lineation (specially *Beola Isorno*). White mica is medium grained (e.g. *Beola Argentea*), chlorite and chloritized biotite are widespread.

From a geochemical point of view, the orthogneisses of the Monte Rosa, Orselina-Moncucco-Isorno and the Monte Leone nappe are originated from peraluminous sub-alkaline granites, with high-K calcalkaline affinity and SiO_2 contents ranging mainly from 68% to 78% wt. A compositional gap is observed in the Monte Leone rocks: two different groups are present, one between 62 and 66% wt. and the other between 70 and 78% wt. of SiO_2 (Cavallo *et al.*, 2004b). The varieties from the Fobello-Rimella schists have the most heterogeneous composition, ranging from metabasites (i.e. *Verde Vogogna*) up to leucocratic orthogneisses.

The strong textural anisotropy (foliation and lineation) has a strong influence on the physical-mechanical properties (particularly compressive and flexural strength, Regione Piemonte, 2000; Cavallo *et al.,* 2004b): **Table 1** and **Table 2** report the technical properties for *Serizzo* and *Beola*, respectively. Surveys in historical buildings testify to the excellent durability of both materials, with sporadic cases of granular disaggregation and exfoliation (especially the varieties from Vogogna – Fobello Rimella schists). Low water absorption, high compressive and flexural strength, as well as good wear resistance make these materials very suitable for outdoor use or in high traffic areas. Due to the planar anisotropy, the load should be applied orthogonally to the foliation.

***Serizzo* and *Beola* exploitation**

The first traces of *Serizzo* and *Beola* gneisses exploitation date back to the Roman period (probably from the exploitation of erratic boulders and stones present near the river): indeed, *Beola* were used for the construction of the *Tempietto Lepontico* (X – XII century) in Roldo Village (Montecrestese). Their applications are visible in many examples of local, national and international architecture (Pala House, Walser Houses, Frankfurt airport's pavement, etc.). One of the main reasons for the development of the VCO stone trade was the presence of the Salt Road, which connected Northern Europe to Italy, crossing the VCO area along the Toce River: the salt was locally paid for with dimension stone (which represented the wealth of the VCO area).

In the past and until the XIX century these materials were exploited *in situ* from erratic boulders and coarse material present near the rivers and streams or on mountain/hillsides (local called *predere*: scree, loose rocks on a cliff, or alluvial deposits pertaining to the Toce river or local streams). The quarrying activity was based on the use of "*cugnere*" (constituted by a series of wide and deep holes, in which birch or oak wedges were introduced; once wet, they expanded and caused the stone to split; their technological evolution is the "*punciotto*", a rock splitting wedge). From the XIX century gneiss exploitation and trade grew more and more; new quarries were opened and the quarrying technique developed, with a more rational use of explosives.

The greatest development took place in the early 1900s as a railway line and the construction of the Symplon tunnel in 1906 facilitated the export of local products. This new opening to foreign markets had both positive and negative effects: at the beginning, new markets ready to adsorb materials from VCO generated richness for the area, but in 1908 the Swiss government imposed a unilateral excise duty (6.0 Lire/ton; Lire was the Italian currency) for the *Beola* coming from VCO, with consequent impact on the VCO industry (Chiaromonte 1985). Furthermore, the increasing use of of concrete in construction and difficult working conditions in the quarries led to the closing of several quarries before the World War II.

After WW2 new quarries were opened and working conditions strongly improved (Dino & Cavallo, 2015) (**Fig. 5**). Between 1960 and 1970, bench splitting and the secondary cutting were performed, once or twice a year, using gunpowder arranged in coplanar cylindrical holes, perpendicular to the main foliation (i.e. the surface which splits most easily, called *pioda* or *verso*); the detonation was performed by means of electric detonators or detonating cord.

The global crisis in the building sector during the 2000s caused a decrease in Serizzo and Beola exploitation: several quarries have closed since the year 2000. The quarrying technique nowadays utilises a combination of explosive and diamond wire cutting: after the cutting, the blocks are detached from the deposit (**Fig. 6**). As far as the overall dimension stone reserves are concerned, an exact value of the total available reserves of Serizzo and Beola seems to be indeterminate, but the extent and thickness of the geological formations containing these stones allow inference of a sufficiently large volume to secure a long-term production. All the commercial main types are largely available for replacement and restoration works (with the only exception being the light coloured Beola Bianca of the Monte Rosa nappe), and there is no reason to expect such availability to decrease within a sufficiently long period of time.

***Serizzo* and *Beola* processing**

The productive system in the VCO area consists of three different kinds of companies. There are almost exclusively quarrying enterprises, whose main work is extracting raw blocks, perhaps supplemented by rough workmanship directly on the quarry floors; these companies often also have workshops handling the extracted material. Other companies are of the manufacturing type, devoted both to turning out considerable amounts of gangsaw slabs and to making products of every type on the basis of specific orders. Finally, there are numerous businesses of the artisanal type, almost all family-run, low on mechanization but specialized in producing small manufactured items, such as crazy-pavement pieces, produced by splitting.

In processing, both *Beola* and *Serizzo* undergo the classic stages of primary cut, surface finishing, secondary cut and (possible) accessory work. Primary cut is typically carried out by means of the traditional gang-saws and giant-disk saws, but, over the last years, diamond-multiwire installation is progressively increasing.

The most common semi-finished pieces are slabs and thick-solid pieces; small formats (tiles), especially if thin, constitute a production cycle of minor importance.

Among the surface treatments, *Beola* and *Serizzo* are very versatile, and can accept water-jet finishing, antiquing and brushing. Unlike many other dimension stones, where it is essentially only polishing that renders justice to their chromatic and aesthetic features, *Beola* and *Serizzo* are valorised with almost any surface finishing. All the so-called "rustic" treatments are possible, from the saw-plane surface to the impact-shock finishing (chiselling, ribbing, bush-hammering, sand blasting).

Important differences can be appreciated when the selected surface finish is splitting. Both stones exhibit a clear directionality, i.e. a dominant foliation, of the entire rocky mass, ("*verso*" or "*pioda*"); this "*verso*" can be appreciated at any scale, from the macro-scale (e.g. in the quarry) to the small one (e.g. a tile, **Fig. 2** and **Fig. 3**), up to the microscopic scale (a thin section, **Fig. 4**). This feature determines the divisibility (splitting performance), which, in its turn, defines both the cleanness of the separation surfaces obtainable and how close said surfaces may be to one another (spacing).

Beola and *Serizzo* have the rare characteristic of being both dense and easily cleaved; they are dense enough to be extracted in blocks yet have such a penetrative *verso* that they can be split with chisels and/or hatchets. But the splittability of the *Beola* is much easier and "precise" than the one of the *Serizzo* (mylonitic vs. gneissic microstructure), and this explain why *Beola* can provide extremely thin pieces and almost semi-planar surfaces. This feature also explains why *Beola* was in the past the preferred by local residents; they were more easily worked with simple manual tools even without being extracted in big blocks. *Serizzo* maintains this feature but the lower level of penetrativeness (due to its relatively coarse gneissic microstructure) make the same splitting operations slightly more difficult, although always possible. Several working tools are adopted to produce slabs, tiles, curbs, etc. from massive blocks: e.g. diamond frame-saws, gang-saws with lime + abrasive shot, diamond wire machines, polishing machines, and multidisc milling cutters. Stone working activities cause the production of residual sludge, which represents a serious environmental and economic problem both for the stone industry and communities. Indeed, most of time, residual sludge is landfilled because of the difficulties in reusing it. Such material is characterised by a very fine size distribution, high heavy metal and TPH (Total Petroleum Hydrocarbon) content (Dino *et al*. 2016; Careddu & Dino, 2016). In general, residual sludge can be used as waste for environmental restoration or for cement manufacture. Several research projects are currently investigating the possible reuse of sludge as new products: i.e. filler material and new soil for environmental rehabilitation, waterproof material for landfill covering, filler material for ceramics and geo-polymers (Dino *et al.,* 2015, a,b; Dino *et al*. 2016). As for silicatic sludge, at Italian level, most of these researches (WeCare commitments – EIT Raw Materials, 2016-2019; ReMix Project, 2011-2012; Lapidei del Lago Maggiore e dell'Ossola, 2011-2013, Interreg IIIA VCO-Canton Ticino CH, 2002-2004), have been carried out using sludge produced during the processing of *Serizzo* and *Beola*, confirming that the stone sector in VCO, even if in crisis, is active in finding sustainable alternative to waste disposal.

***Serizzo* and *Beola* applications**

Ossola is made of stone the promotional brochures for the Ossola Valley remind us, in tribute to that hard and yet compliant material that has forged everything in that area. In fact, the trained eye cannot miss the role that stone plays in the landscape: its presence is tangible in the streets and on the houses and roofs (**Fig. 7.a**), in architecture, agriculture and even the commonest objects of daily use. While in other rural societies many constructions are in wood, in Ossola they are in stone. Even today some upper valley villages proudly display an endless range of manufactures made from stone: walls, roofs, streets with carriage tracks for vehicular traffic (**Fig. 7.b**), terraces and window ledges (most often decorated), drinking troughs (**Fig. 7.c**), property boundaries marked by adjacent slabs embedded in the ground, supports for vines (**Fig. 7.d**). And then stone posts, typical Roman-style roof-gutters, grindstones and millstones, even household objects like wood-burning stoves (**Fig. 7.e**) for home heating (*furnet*) or the *laveggi*, cookware made from *laugera*, a green soapstone. Almost as unique are the "hats" of the characteristic "mushrooms" on which sit the Walser houses (**Fig. 8),** typical local homes made mostly from wood but always featuring a constant presence of stone, such as the flooring for the kitchens and stairs, the fireplaces and aforementioned wood-burning stoves. Also made of stone was – and still is – a whole series of minor works: sidewalks, curbs, low walls and their coping, milestones, carriage tracks, benches, fountains, sewer pipes (now rarely seen) etc. A longer list of applications could be here included, but those listed above reflect the versatility of these two stones and the permanent footprint they left on their source region. *Beola* and *Serizzo* are Ossola materials par excellence; certainly, the other stones extracted in the valley are also important, but the great differences in output volume between these and the others inevitably led to the wider use (**Fig. 9**) and knowledge of the former two. In many cases it is not easy to establish a sharp boundary between their usage areas as they are frequently found together in many places.

The term *Beola* (or "*bevola*", the name of Beola in local dialect) comes from the time, in the XVI century, when the village of Beura was the centre of quarrying; *"HVNC LAPIDEM BEVRA DEDIT" ("Beura gave this stone")* is the writing dated 1513 found on an existing sarcophagus once in the Franciscan monastery in Domodossola and later moved to a chapel in Pallanzeno. Although *Beola* began to be used outside of the Ossola Valley towards the end of the XIII century, we cannot exclude that *Beola* stone may have been "exported" by the Romans since the ancient Roman road passed right through that town. Because they can be cleft and worked through splitting, *Beola* have always been the materials most practical and suitable to local building (and other uses) as demonstrated in some of the valley's municipalities.

The origin of the term *Serizzo* (or *Sarizzo*), according to some sources, seems related to the dialect of the city of Milan, where "*Sarìzz*" means "schistose rock–gneiss", but the attribution deserves further historical research. Use of *Serizzo* was already widely documented since the age of the Communes and the Viscontis up to the end of the XV century; the city of Milan played a crucial role in "promoting" these two Ossola stones (together with the others extracted in the valley, such as the *Granites of the Laghi* and the *Candoglia Marble*), and in fact they can be seen on the towers of the Sforzesco Castle, in numerous parts of the Duomo (for the plinth and the piers) and various other churches (Sant'Ambrogio, San Simpliciano, San Eustorgio), in parts of Palazzo della Regione, in a multitude of columns in several buildings (e.g. the old Ospedale Maggiore in Milano, now University of Milan), and in a vast range of other buildings, from residential to commercial, military to religious (Porta Nuova, Porta Ticinese, Casa Borromeo, etc.).

The first evidences of a significant use of these stones - most of all, the *Beola* – was in the Roman period. At the end of the I century B.C., the Romans, after conquering the Ossola Valley, constructed realized an important net of mule-tracks, the structure of which had no equals (Antiquarium Mergozzo, 1978; Adam, 1994). Local availability of large slabs of *Beola* allowed the Romans to create extremely regular mule-tracks, with the slabs arranged in a transversely with respect to the direction of travel. The existence of a Roman road is confirmed by a Latin epigraph, dated 196 A.D., engraved in a rock near Vogogna village, and reporting the names of two consuls: Caio Domizio Dextro and

Publio Fusco. Other remnants - a 500 m long stone path - entirely cut in the rock, remains visible in the area between the villages of Beura and Cuzzago, where the road is located 100 metres above the Toce river, protected from floods, and close to the villages of Montecrestese, Oira and Baceno, in the northern part of the valley. The road is likely the oldest road between Italy and Switzerland. Historically, *Beola* and *Serizzo* have been utilised for entire rural buildings and villages and for the construction of local religious and historical buildings, examples of which are represented by *S. Gaudenzio Church*, in Baceno village), the Domodossola city centre (**Fig. 10**) and *Madonna di Campagna Church*, in Pallanza. The village of Roldo, belonging to the municipality of Montecrestese, is a magnificent example of a rural village (completely built in local stones), where most of the original buildings and structures are well preserved. The Tempietto Lepontico, dating back to the I century B.C. (Roman period), is the best representative of this heritage. The village of Canova, in the municipality of Crevoladossola, shows interesting examples of houses, dating back to the XII-XIV century, the structure of which is astonishingly well preserved, with the connection among the stone ashlars in good conditions. Some years ago, a group of American citizens founded a local association (Canova Association) with the specific aim to orientate the owners of the houses to the culture of the conservation and restoration. Thanks to it, this village is nowadays completely restored using exclusively local materials and techniques and is inhabited.

In many public areas there are cobbled pavements or streets paved with slabs made from elements laid edge to edge or as crazy pavement. In every case the material had been procured on site, either taking rounded stones from streambeds or splitting boulders found just about everywhere in the zone. Roofing with *Beola* deserves special mention (Simonis, 1976): all old roofs (e.g. Pala House, XV century), whether in the cities, towns or valleys, were made of wooden rafters and slabs of stone (the so-called *piode*). The most fortunate were able to use *Beola*, perfectly cleavable into very thin pieces, a fact that has always made it a prime reference material. Those unable to use *Beola* used *Serizzo*, less easy to cleave into cleanly split pieces (although there are some exceptions). There is an unmistakable mixture of style, technique and engineering in planning, and realizing, the roofs; a unique mix which make the Ossola Valley roofs different from all others.

Over time, due to the progressive development of transportation routes, the use of *Beola* and *Serizzo* progressively expanded, both at national and international scale (Rodolico, 1995). When the Naviglio Grande Channel was made navigable down to Milan (from XIII century), it facilitated stone transportation to the city of Milan itself and with other important cities of Lombardy. More recently, in the early 1900s, the two stones have increasingly been used for big civil engineering works (dams and tunnels), and have progressively assumed the ornamental role they play today; the continuity of their use has created a cultural legacy. *Serizzo* and *Beola* are currently largely exported to all the most important countries of Central Europe (France, Switzerland, Germany), where are mostly used for cladding purposes, flooring, paving and basic architectural elements of residential buildings (lintels, thresholds, sills, skirting-board etc.), but they also been used further afield, in Singapore airport.

Related heritage issues

Association Dynamics

At present one trade association is operating in the Valley, namely Assograniti, founded in 2001, to which most, but not all, the area's operators belong. The presence of an Association denoted a tendency to group together and to guarantee a synergic representation of the stone sector both at local and national level.

C.S.L. (Centro Servizi Lapideo)

The C.S.L. is a multi-purpose facility, located in Crevoladossola, originating as a laboratory for testing and researching materials from a project presented by the VCO provincial government within the Piedmont Region's 2000/2006 integrated area plans. It was set up as a joint-stock consortium whose shareholders are universities (Turin University and Turin Polytechnic, Milan-Bicocca University) and the boards, institutions, trade associations and companies in the area. Its "core" consists of an up-to-date laboratory engaged in conducting technical tests for the stone and other sectors (building, water resources, etc.) and in experimenting, job training, scientific and technological innovation, thanks to the presence of the four universities among its founding partners. A similar laboratory has been planned in Sardinia (Careddu et al. 2013), to prove that stone promotion, knowledge on stone materials and the importance of exploiting dimension stones as a whole (both the main products and the waste) are a need and an opportunity for local economy.

DIADI Project

DIADI 2000 Project [2003-2006: *DIADI – Diffusione dell'Innovazione nelle Aree a Declino Industriale* (= Bringing Innovation into Industrially Declining Areas)] was a project aimed at stimulating growth in the economic system through technological innovation. Within this context it developed a sub-project to "Valorise and qualify VCO stone-sector production", whose final goal was to identify the finest uses of stone in building and to promote correct stone use by drafting special contracting specifications. It was intended to bring back the quality of the past, clearly defining the quality and supply specifications for building materials and rules for their correct use. In particular, among other things, it intended to:

- impose an indigenous origin for the natural materials used, as an essential prerequisite in the tender's technical report;
- analytically describe the type, quality and technical characteristics of the materials;
- prescribe technical verification that the material supplied is the material ordered, with checks on supply following the dictates of EC marking.

International Sculpture Award

In 2007 and 2008, in order to enhance the local stone industry and the beef industry, that have long represented important resources for the Ossola Valley, Gal Azione Ossola in collaboration with APA Novara and VCO (provincial association of cattle breeders), and the Association Assograniti, within the framework of a Trans-National project (Italy-Switzerland), have promoted an international competition of sculpture: STONE AND ITS PASTORAL MUSE, using exclusively the local stone *Serizzo* (Antigorio variety). The initiative aims to emphasize the deep and long-lasting bond between the local stone and the *Bruna Alpine* breed of cattle, a relationship which has characterized family life in a rustic landscape. The artist was required to be the creator of a sculpture of this Pastoral Muse, which, after the competition, has been placed in one of the central squares in Domodossola.

"Tones on the Stones"

"Tones on the Stones" is a yearly exhibition, in which international musicians, artists, poets, theatre groups etc. perform in the context of a VCO stone quarry, including *Serizzo* and *Beola* quarries). Since 2007, the aim and the challenge of Tones on the Stones project is to highlight the aesthetic as well as the historical value of the stone quarries of VCO, by giving spectators a strikingly new viewpoint and enabling them to appreciate the rugged angularity of these places through new eyes.

Sustainability

Three projects which, in the light of the recent approach to natural resources, their use and the basic concepts of circular economy, can be appropriately considered as valid examples of sustainability *s.l.* Two projects are Italian-Swiss cooperative projects, in the framework of the *Interreg IIIA Community Enterprise Program*. One concerns the re-use of the residual sludge coming from stone-working and was developed from 2003 to 2005. The main aim of the studies was to propose feasible solutions for completing and concluding the dimension stone production cycle by looking into commercial uses for the sludge by-product. The he VCO proved able to deal with the problem more seriously than other Italian stone areas, and complied with current laws, not an easy task when you have to re-direct an entire community from a concept of waste (even a non-hazardous type, like stone waste) to the more advanced concept of by-product. A second project, (2006 – 2008) called O.S.M.A.T.E.R (*Osservatorio Subalpino Materiali Territorio Restauro* – Sub-Alpine Observatory on Materials, Territory and Restoration) was instead concerned with valorising and recouping the area's artistic, historical and building heritage, partly by creation of an observatory networking with research centres and local boards and institutions (Dino & Cavallo, 2015). Here, as well, many organizations were working together: Chambers of Commerce, Associations, universities, private companies, craftsmen's associations, as well as, on the Swiss side, the Italian-Swiss trade-school university. A third project is called AlpStone "Traditional architecture promotion, man-made landscape and built-up areas protection" *Interreg project (2010-2013)*, which aimed to improve and recover the local traditional and historic heritage (buildings and infrastructures) to be promoted in the fields of tourism and hospitality, to create an incentive for the local economy of Verbano Cusio Ossola. (http://www.alpstonehome.eu/en-GB/our-project/mission/).

Conclusion

Serizzo and *Beola* gneisses show good technical characteristics (e.g. low water absorption, high compressive and flexural strength, good wear resistance) which make these materials very suitable both for indoor for outdoor uses. Petrographically they show similar characteristics, consisting of quite homogeneous quartz, K-feldspar (orthoclase or microcline), plagioclase, biotite and muscovite. The main differences between *Serizzo* and *Beola* gneisses are related to the rock fabric (generally mylonitic) and to the presence of accessory/secondary minerals in *Beola* gneiss.

Given their similarity in petrography and association in the VCO district, coupled with their international use, it is suggested that *Serizzo* and *Beola gneisses* may be considered, from a heritage perspective, together as constituent heritage stones in a Verbano-Cusio-Ossola (VCO) Gneiss Province that possibly deserves international recognition as a Global Heritage Stone Province.

Individually *Serizzo* and *Beola* may also deserve recognition as Global Heritage Stone Resources, given their use since Roman period, their longstanding availability and workability and utilisation in many historical buildings, monuments and utilitarian manufactures, related to local and national heritage. *Serizzo* and *Beola* also have extensive modern use in internal and external paving or facing, both in Italy and internationally.

Trade in these stones, which characterized (and still characterizes) the VCO territory, has been affected by the recent economic crisis in the national and international market, so that in recent years many quarries, even if active, are no longer productive. Due to the global economic situation and strong competition with other countries (e.g. China, India), the risk of a collapse in *Serizzo* and *Beola* production is possible.

The creation of specific projects, ranging from the preservation of historical memory (e.g. OSMATER) to the virtuous reuse of waste materials from the dimension stone industry (e.g. SMART GROUND H2020 project, Dino *et al*. 2017), are desirable and essential if the synergy between tradition, heritage and resource development is to be preserved

Consequently, recognition of a "Verbano-Cusio-Ossola (VCO) Gneiss Province" with *Serizzo* and *Beola* recognised, in addition, as a "Global Heritage Stone Resource" would be beneficial.

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Figure captions

Figure 1. Geological sketch-map of the Verbano-Cusio-Ossola area. The main quarry areas (both active and historical) are located: *Serizzo* (*Antigorio*, *Formazza*, *Sempione* and *Monte Rosa*); *Beola* (*Grigia*, *Bianca*, *Striata*, *Ghiandonata*, *Favalle*, *Argentea*, *Isorno*, *Quarzite Bianca* and *Verde Vogogna*); Crevola dolomitic marble (*Palissandro Blue*, *Palissandro Nuvolato*, Palissandro *Bronzetto*, *Palissandro Bluette*); soapstones (*Verde Cisore*); basic granulites (*Anzola Gabbro*); calcitic marbles (*Candoglia*, *Ornavasso* and *Vallestrona* marbles); granites (*Rosa Baveno*, *Bianco Montorfano* and *Verde Mergozzo*) and dolostones (*Pietra di Arona*).

Figure 2. Main *Serizzo* varieties: *Serizzo Antigorio (a)*; *Serizzo Formazza (b)*; *Serizzo Monte Rosa (c)*; *Serizzo Sempione (d)*. Base of each picture is approximately 25 cm (tiles pictures).

Figure 3. Main *Beola* varieties: *Beola Bianca (a)*; *Beola Ghiandonata (b)*; *Beola Grigia (c)*; *Beola Favalle (d)*. Base of each picture is approximately 25 cm (tiles pictures).

Figure 4. PLOM image (crossed polars) of a *Beola Bianca* thin section, with marked mylonitic foliation and a rotated K-feldspar (microcline) porphyroclasts (a); PLOM optical microscopy image (crossed polars) of a *Serizzo Antigorio* thin section, with gneissic texture and biotite lamellae (b); SEM back-scattered electron image of *Beola Favalle*: dark areas are represented by quartz, medium-gray by plagioclase (oligoclase) and brighter spots by biotite (c); SEM back-scattered electron image of *Serizzo Antigorio*: detail of a poikiloblastic K-feldspar porphyroclasts. Scale bar for PLOM thin sections is 250 µm (d).

Figure 5. Aerial view of a *Beola* quarry (quarry activities from II World War).

Figure 6. After the detachment from the deposit, the overturning of a *Serizzo* bench**.**

Figure 7. Typical roofing in Valle Anzasca, Pecetto locality: Pala House, a national monument (end of XV century) (a); A traditional street with carriage tracks for vehicular traffic, made of *Beola* (b). A traditional drinking trough (*Beola*) close to a rural house (c). The characteristics supports for vines (*Beola*) (d). A traditional stove in *Serizzo* (e).

Figure 8. Left: partial view of a typical Walser house; right: the characteristic stone “mushrooms” at its base.

Figure 9. The castle in Vogogna village (XIV century).

Figure 10. The historical central square in Domodossola, the largest city in Ossola valley.

Table 1. Technical properties of some *Serizzo* varieties. Source: ASSOGRANITI.

Reference standards in brackets.

	SERIZZO FORMAZZA	SERIZZO ANTIGORIO	SERIZZO MONTEROSA	SERIZZO SEMPIONE
Water absorption (%)	0.4 (UNI EN 13755)	n.a.	0.4 (UNI EN 13755)	n.a.
Coefficient of imbibition (‰)	3.05 (UNI 9724/2)	3.75 (UNI 9724/2)	3.88 (UNI 9724/2)	2.75 (UNI 9724/2)
Apparent volumetric mass (kg/m^3)	2661 (UNI EN 1936)	2730 (UNI 9724/2)	2649 (UNI EN 1936)	2640 (UNI 9724/2)
Compressive strength (MPa)	139 (UNI EN 1926)	145 (UNI EN 1926)	179 (UNI EN 1926)	161 (UNI 9724/3)
Flexural strength (MPa)	14.4 (UNI EN 12372)	16 (UNI 9724/5)	11.3 (UNI EN 12372)	14 (UNI 9724/5)
Impact strength (cm)	98 (UNI U32.07.248.0)	82 (UNI U32.07.248.0)	65 (UNI U32.07.248.0)	82 (UNI U32.07.248.0)
Knoop micro-hardness (mean value - MPa)	4729 (UNI 9724/6)	4576 (UNI 9724/6)	4686 (UNI 9724/6)	4094 (UNI 9724/6)
Compressive strength after freeze-thaw cycles (MPa)	119 (UNI EN 12371 + UNI EN 1926)	132 (UNI EN 12371 + UNI EN 1926)	153 (UNI EN 12371 + UNI EN 1926)	150 (UNI 9724/3)
Flexural strength after freeze-thaw cycles (MPa)	11.9 (UNI EN 12371 + UNI EN 12372)	n.a.	10.2 (UNI EN 12372)	n.a.
Ultrasound propagation speed (m/sec.)	2508	2295	3050	2261

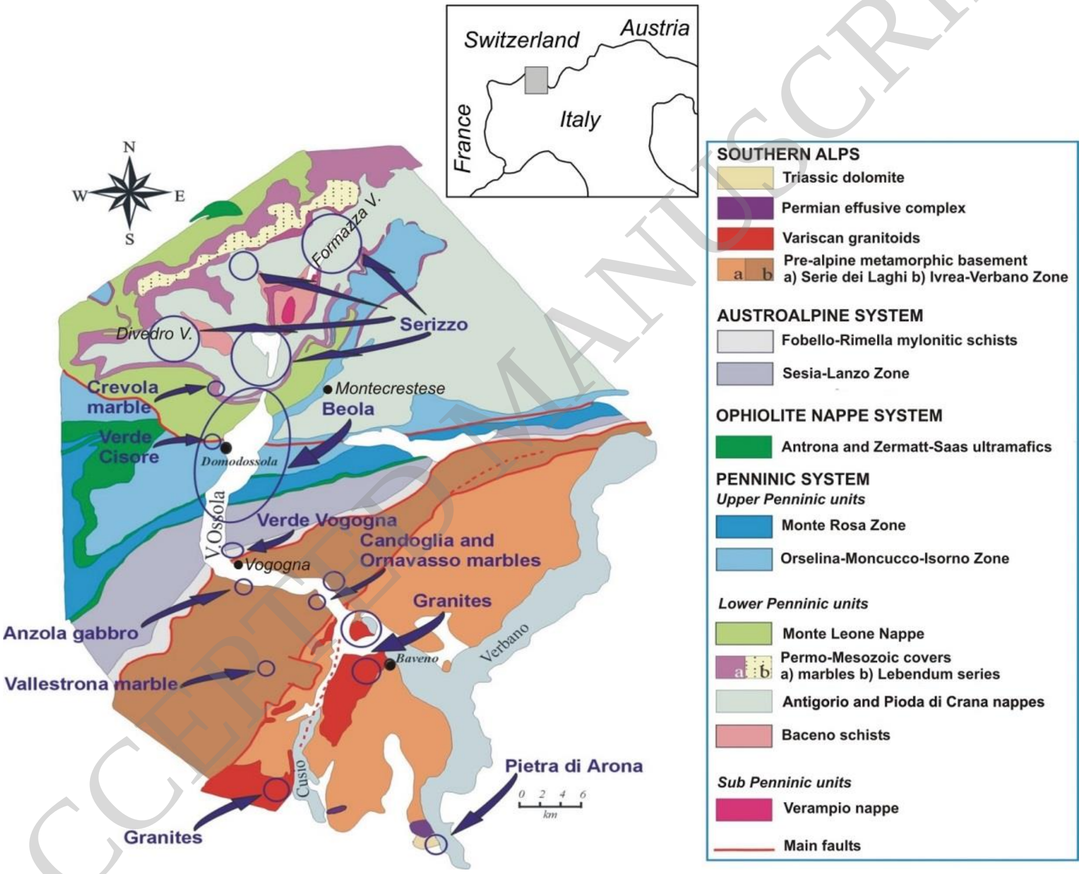
Coefficient of linear thermal expansion (10^{-6}/° C)	11.25	12.75	13.20	10.50
Abrasion resistance (mm)	16.5 (Capon method)	17.8 (Capon method)	18.3 (Capon method)	n.a.

Table 2. Technical properties of some *Beola* varieties. Source: (1), (2), (4): DOMOGRANITI S.p.A. and ASSOGRANITI; (3), (5): ASSOGRANITI.

Reference standards in brackets.

	BEOLA BIANCA (1)	BEOLA GHIANDONATA (2)	BEOLA FAVALLE (3)	BEOLA GRIGIA (4)	BEOLA ISORNO (5)
Water absorption (%)	0.41 (UNI EN 13755)	0.39 (UNI EN 13755)	n.a.	0.36 (UNI EN 13755)	n.a.
Coefficient of imbibition (‰)	n.a.	n.a.	2.90 (UNI 9724/2)		2.90 (UNI 9724/2)
Apparent volumetric mass (kg/m^3)	2629 (UNI 9724/2)	2570 (UNI 9724/2)	2630 (UNI 9724/2)	2666 (UNI EN 1936)	2630 (UNI 9724/2)
Compressive strength (MPa)	104 (UNI 9724/3)	164 (UNI 9724/3)	178 (UNI 9724/3)	149 (UNI EN 1926)	178 (UNI 9724/3)
Flexural strength (MPa)	21 (UNI 9724/5)	19 (UNI 9724/5)	14 (UNI 9724/5)	11.2 (UNI EN 12372)	14 (UNI 9724/5)
Impact strength (cm); (J)	100 cm (UNI U32.07.248.0) 6.6 J (UNI EN 14158)	85 cm (UNI U32.07.248.0) 7.1 J (UNI EN 14158)	97 cm (UNI U32.07.248.0)	97 cm (UNI U32.07.248.0)	97 cm (UNI U32.07.248.0)
Knoop micro-hardness (mean value - MPa)	4156 (UNI 9724/6)	3892 (UNI 9724/6)	5181 (UNI 9724/6)	5181 (UNI 9724/6)	5181 (UNI 9724/6)
Compressive strength after freeze-thaw cycles (MPa)	190 (UNI 9724/3)	160 (UNI 9724/3)	172 (UNI 9724/3)	143 (UNI EN 12371 + UNI EN 1926)	172 (UNI 9724/3)

Flexural strength after freeze-thaw cycles (MPa)	n.a.	n.a.	n.a.	10.5 (UNI EN 12371 + UNI EN 12372)	n.a.
Ultrasound propagation speed (m/sec.)	2321	2237	2361	2361	2361
Coefficient of linear thermal expansion (10^{-6}/° C)	n.a.	n.a.	13.50	13.50	13.50
Abrasion resistance (mm)	18.0 (Capon method)	n.a.	n.a.	17.5 (UNI EN 14157)	n.a.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Domodossola
V. Ossola
Verde Vogogna
Vogogna
Candoglia and Ornavasso marbles
Granites
Anzola gabbro
Baveno
Verbano
Vallestrona marble
Cusio
Pietra di Arona
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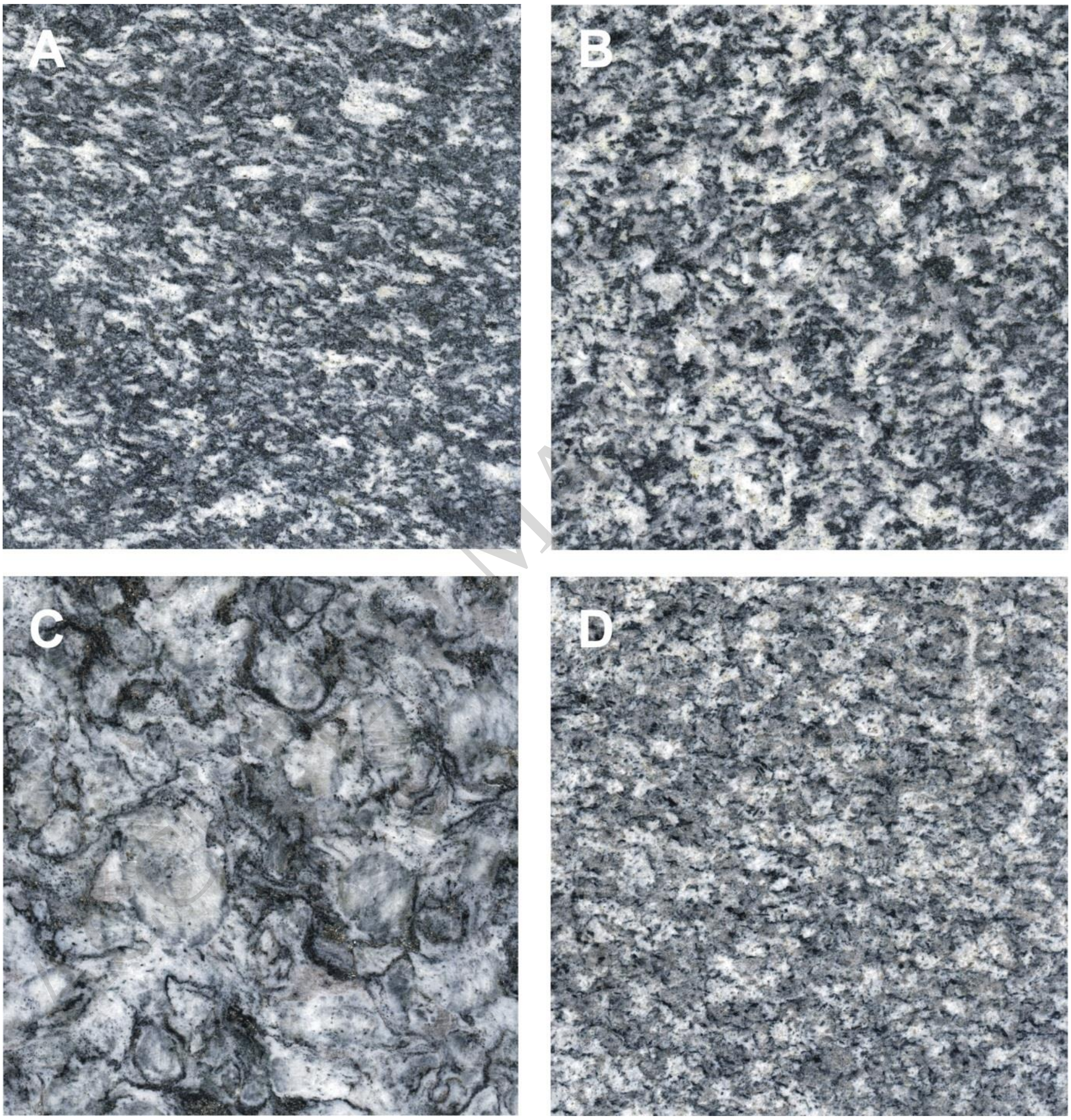
Granites
SOUTHERN ALPS
Triassic dolomite
Permian effusive complex
Variscan granitoids
Pre-alpine metamorphic basement a) Serie dei Laghi b) Ivrea-Verbano Zone
AUSTROALPINE SYSTEM
Fobello-Rimella mylonitic schists
Sesia-Lanzo Zone
OPHIOLITE NAPPE SYSTEM
Antrona and Zermatt-Saas ultramafics
PENNINIC SYSTEM
Upper Penninic units
Monte Rosa Zone
Orselina-Moncucco-Isorno Zone
Lower Penninic units
Monte Leone Nappe
Permo-Mesozoic covers a) marbles b) Lebendum series
Antigorio and Pioda di Crana nappes
Baceno schists
Sub Penninic units
Verampio nappe
Main faults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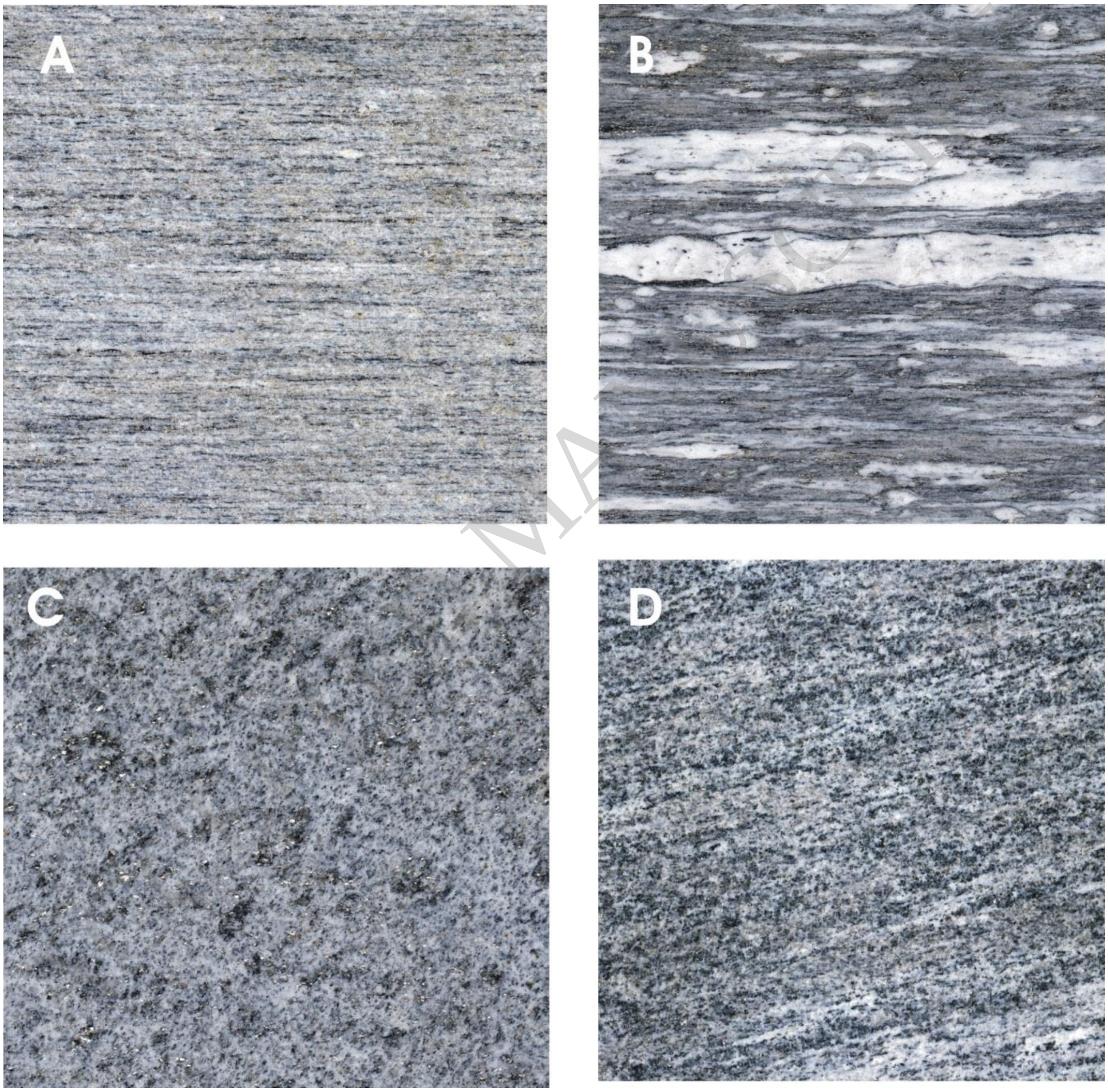
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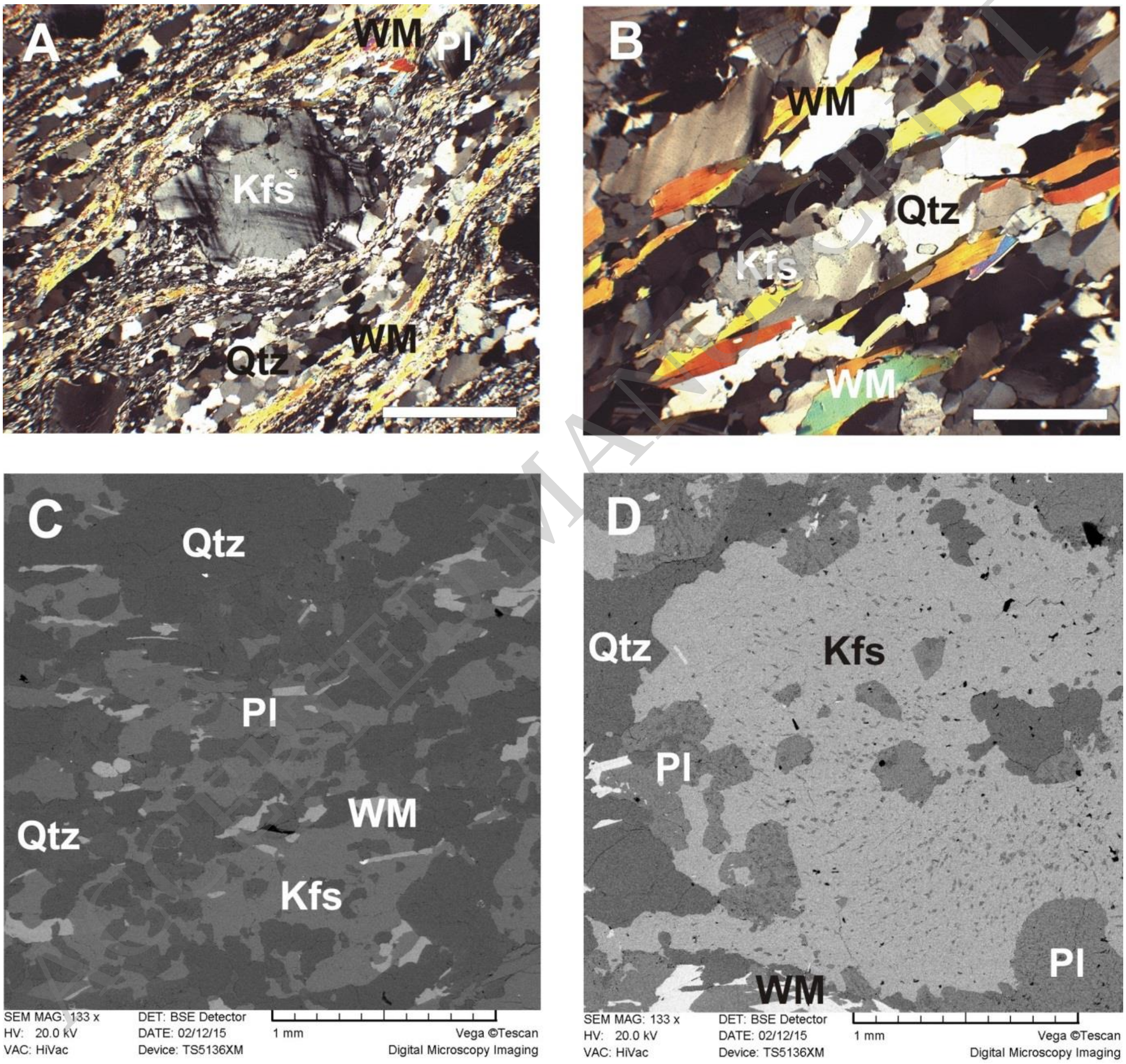
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SEM MAG: 133 x
HV: 20.0 kV
VAC: HiVac
DET: BSE Detector
DATE: 02/12/15
Device: TS5136XM
1 mm
Vega ©Tescan
Digital Microscopy Imaging
D
Qtz
Kfs
Pl
Pl
WM
SEM MAG: 133 x
HV: 20.0 kV
VAC: HiVac
DET: BSE Detector
DATE: 02/12/15
Device: TS5136XM
1 mm
Vega ©Tescan
Digital Microscopy Imaging


a
b
c


a
b
c
d
e


a
b