

Geological evolution and structural lay-out

The geology of the territory belonging to the province of V.C.O., within its structural context of the western Alps, is too large a subject for this volume. Therefore we have limited ourselves to providing brief, summary information, which necessarily means that some things have been left out. Our purpose is to give a simple overview of the geological-structural meaning and importance of the quarry basins along with the principal geo-lithological and structural characteristics of the stone materials quarried and processed.

The structure of the rock itself and the complex architecture of the western Alps range situated along the structural section of Ossola-Verbano, allows for the reconstruction of principal geological events that took place in the Alps over millions of years, from their Palaeozoic period orogenesis up to the development of the Alps; the latter action began with the Mesozoic ocean (Tetide) and its subsequent closure to the point of collision, an action that is still in progress today, between the African and European continents. It is with good reason that the Ossola region played a decisive role, from the end of the 1800's to the beginning of the 1900's, in the development of modern geological thought and the confirmation of migrational structure theories: it was here, rather than from the entire western Alps sector, that the first models for overthrust mass ranges were created, and the first methodological principles for kinematics analysis were introduced along with the first reconstructions of paleogeographic environments. In more recent times, the V.C.O. territories have become natural laboratories for further study in the earth sciences, from tectonic plate applications to the Alpine ranges, to the development of highly advanced geodynamics and kinematics reconstruction based on integrative interpretations of new geological, geophysical, petrologic, geo-chemical and chemo-physical data.

It is not easy, however, to discuss the geology of the area under examination given the complex layering processes that have happened over time. Strictly speaking, Hercynian history begins approximately 400 millions of years ago (from the Devonian period of the Palaeozoic era) through collisional orogenesis, stratum tectonics, crustal thickening and regional multi-phase metamorphosis, from its original conditions of relatively high pressure (cyanite residue) and moving towards a lower pressure (andalusite). In the late Palaeozoic era, (some 300 to 250 million years ago) a complex magmatic activity took place, with volcanic, sub-volcanic and plutonic manifestations. This activity extended from the Upper Carboniferous period to the Permian or was exclusively Permian, having an affinity to calc-alkaline; the latter is the case with Baveno-Mottarone-Montorfano granite, or Lake Granites, embedded in a pre-existing crystalline deposit (Lake Schists), which underwent metamorphosis and formed during the Hercynian cycle (figure 2). Like the schists in which they are embedded, the granites no longer underwent metamorphosis or successive bending deformation, having maintained, during the higher temperatures of thermal deformation, a surface structural level, a non-axial position and non-metamorphic position in the Alpine range.

Beginning from the Upper Carboniferous period, final erosion and rising processes of the Palaeozoic range produced widespread surface erosion. The following extension of the Permian/Mesozoic crust and the formation of a divergent continental edge brought about the opening up of the Liguria-Piedmont ocean (Jurassic palaeogeography) until arriving the development of the current Alpine range through the evolution in the Cretaceous period (130 million years ago) of the converging compressive crust of the Europe/microplate Adria.

The highest temperatures and level of pressure were reached in Aosta and Piedmont during the height of Alpine orogenesis, from the Cretaceous up to the Oligocene period (30 million years ago), causing metamorphic transformation of the pre-existing rock which, in turn, generated lithotypic deformation, overturning and folding of existing materials, not to mention the positioning of a series of plutonic rock.



It was the orogenetic evolution in the western part of the Alps of the Cretaceous period that led to its current deformed and height structure. The changes took place in three distinctive phases:

- 1) Eo-Alpine event (130-50 million years ago), the long "pre-collisional" evolution of the converging African/European continental edge, characterized by a rapid splitting action of the oceanic crust in the mantle and by the formation of an initial strata range of a NW creep verging on the Adriatic edge; at a deep level, subduction of continental crust edges, leaving traces of high pressure metamorphism in the eclogitic relicts to be found in a good deal of Alpine ophiolite and in the Pennine Nappe and Austro-Alpine groups to the west. In Val d'Ossola, where Meso-Alpine destabilization of the metamorphic combinations of high pressure activity finished, microscopic Eo-Alpine paragenetic evidence was found only in the serpentine rock belonging to the ophiolitic Antrona group;
- 2) Meso-Alpine event (da 51 a 30 million years ago), linked to the definitive closure of the Liguria-Piedmont ocean and to the continental collision stage; this is an event deeply characterized by polyphasic metamorphism and by post-nappe strata phenomena, of various dimensions and in different phases, which formed the Ossola lithology to the north of the Insubric Line (north of Vogogna); temperatures reached their peak at around 550-650°C a pressure of 5-7 kb (kilobar) in the Ossola-Ticino area, with the development of amphibolic and granulitic metamorphic facies (mineralogical association in equilibrium characteristic of medium-high temperature rock) and products of partial melting;
- 3) Neo-Alpine event, distinguished by a series of tectonic processes which created the current structure and the dual vergence of the Alpine range: The Alpine domain, strictly speaking (the northern Alps) was, instead, distinguished by the migration of structures (strata folding, faults) towards the NW, while the Southern Alps were characterized by the spread of structures to the SE. The two domains are separated by a system of faults called the Insubric-Canavesano line.

In the complex of metamorphic and deformation processes of different eras, degrees and intensities, a process of overlapping defined the polyphasic tectonic and metamorphic structure on various scales, which characterizes both the original Palaeozoic bed and the upper Permian-Mesozoic sedimentary layers.

The final result of all this discussion makes it difficult to give a clear reading of the existing geological situation, but in order to focus on the stone quarry basins we may divide the areas under examination into two principal structural domains, from south to north, as follows:

- 1) the area of the Southern Alpine Crystalline Bed, or "Serie dei Laghi" (Series of Lakes) (figure 2), characterized by metasediments of the upper crust with calc-alkaline medium acidic intrusions, in the late Hercynian period in the Permian era, of variable chemism from granodiorite to diorite (Lake Granite from lower Ossola, from Verbano and Cusio); towards the north, again in the southern Alpine orogenesis, on the SE vergence, sits a deep section of crust from the Ivrea-Verbano Zone (lower Ossola, from Candoglia to Vogogna), touching the "Serie dei Laghi" through the Pogallo Line (near Mergozzo); this area is constituted by the so-called Kinzigite Complex (metasediment with high level metamorphic activity) and by an abundance of basic rock with mantle periodotite groupings;
- 2) the area of Alpine Strata Edifice, or European Vergence Orogenetic System (figure 1), in the medium upper part of Ossola situated along deeper structural and radical levels than those of Valsesia and Val d'Aosta, and with a structure that deepens from south towards north. As has already been stated, this zone is separated towards the south by the South Alpine through the Canavese Line (Insubric Line), a system of regional faults which cross Val d'Ossola at the height of the Vogogna-Loro alignment. Along the left versant of Val d'Ossola, in a vertical section, starting from high and descending through the structure we find: from Vogogna a Cardezza, the Austro-Alpine grouping which is linked to the African continent (Sesia-Lanzo grouping); from Cardezza to Quarata (a little north of Beura), the Upper Pennine Nappe domain (Monte Rosa stratum) and the Middle Pennine Nappe (Camughera-Moncucco-Orselina grouping), separated by a level of Mesozoic ophiolite of Antrona that thins out, and which was originally an ocean

rock; to the north of Domodossola lies the Lower Pennine Nappe which is constituted, from top to bottom, from the gneiss strata of Monte Leone, Lebendun, Antigorio overthrusting on the "cupola di Verampio", and separated from each other by "Mesozoic synclines", as Argand called them, and made up of metasediment; the "cupola di Verampio", which is situated a little north of Crodo, is the deepest structural element of the Alpine range, as it is possible to see in the section described in Figure 1. From the same figure, to the NW of Domodossola, it may be observed how the strata of Monte Leone of the Lower Pennine Nappe complex comes into contact towards the south with the Camughera-Moncucco-Orselina (Middle Pennine Nappe) area through a system of flexible or fragile faults of the Sempione Line that moves eastward along the line of Centovalli. Its stress relief displacement made it easier for tectonic denudation to occur in the Lower Pennine Nappe in its rising phase. The Lower Pennine strata are prevalently made up of granite orthogneiss (late Palaeozoic protoliths of Alpine metamorphism) and are characterized by enormous isoclinal folds, sometimes flattened down, formed after the overlapping phases of the Eo-Alpine era (figure 1).

