

# MATERA BUILDING STONES: CHEMICAL, MINERALOGICAL AND PETROPHYSICAL CHARACTERIZATION OF THE CALCARENITE DI GRAVINA FORMATION

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**Abstract** – Matera (Basilicata, southern Italy) was awarded the World Heritage Site status by the UNESCO since 1993, and has been named the European Capital of Culture in 2019. It is one of the most ancient towns in the world, whose historical centre was totally built by a weakly lithified and highly porous lower Pleistocene sedimentary building stone, known as *Gravina Calcarenite*. This easily workable rock was quarried since prehistoric times, and it was used for building different kinds of constructions from the rupestrian settlement to gorgeous historic palaces during the XVIII century. Calcarenite, however, can be an extremely heterogeneous building material depending on the composition of the particles and their characteristics. After a geological survey, it was possible to recognize two main varieties of this building stone, which were in turn subdivided into six lithofacies (corresponding to sub-typologies of building stones). As a first approach, we have characterized, in terms of building stone quality, six lithofacies: basal bioclastic calcarenite, calcirudite-microconglomerate lithofacies, lithoclastic calcarenite, large bivalve bioclastic calcarenite, rhodolith bioclastic calcarenite, and fine bioclastic calcarenite. We focused on the three typologies that were mainly used as building stone (lithoclastic calcarenite, large bivalve bioclastic calcarenite, and fine bioclastic calcarenite). Mineralogical, petrographical and petrophysical analyses have been carried out according to European standard rules to highlight the main characteristics of

the different calcarenite types when used as building stones. These three lithofacies show different petrophysical behavior indicating that large bivalve calcarenite and lithoclastic calcarenite lithofacies have slightly different but characteristic mechanical properties related to the primary influence of grain composition, early cementation and micrite contents. Moreover, fine bioclastic calcarenite lithofacies results to be the worst building stone because it is intensely heterogeneous in porosity, cementation and general petrophysical features because of its intense bioturbation.

**Keywords:** Building stone, petrographic characterization, petrophysical properties, cultural heritage

## I. INTRODUCTION

The Gravina Calcarenite is widely used as a building stone in Puglia and in the eastern sector of the Basilicata region (Southern Italy), up to the present day, thanks to its wide availability and easy workability. It turns out to be a building stone especially useful for structural and decorative elements [1-5]. For this reason, since prehistoric time the Murgia area has been inhabited by shepherds or small groups of people: in the beginning inside natural caves and, then, in excavated houses. The Sassi of Matera, i.e. the old district of the city, represents one of the best preserved rupestrian site in southern Italy. It is UNESCO site since 1992 and represents a perfect example of both a geosite and cultural and natural

heritage site. The traditional rock-cut human settlement adapted perfectly to its geomorphological setting and ecosystem, showing a cultural evolution in harmonious relationship with its natural environment over more than two millennia [6]. As described by several authors [2, 7-10], the Gravina Calcarenite is an extremely heterogeneous formation. It is a Pleistocene rock that overlies the Cretaceous Altamura Limestone. It is characterized by two main members which are recognized on the basis of the relative abundance of skeletal or lithoclastic grains [8]. At the base of the Gravina Calcarenite Fm, a lithoclastic member is observed, whereas the bioclastic member can be detected in the upper part [9, 11] After a detailed lithological survey, we have further divided the two members into six sub-typologies [12,13] well recognizable in the Matera area. In this work we characterize them with a focus on the main typologies which have been extensively quarried for building the ancient town of Matera. The aim of this work is to determine the petrophysical properties of the calcarenites considering the main textural and compositional features.

## II. GEOLOGICAL SETTING

The Calcarenite di Gravina Formation is a lower Pleistocene stratigraphic unit onlapping the Cretaceous Altamura limestone successions of the Apulia Foreland. It forms continuous exposures of intrabasinal biocalcarenites and biocalcirudites and/or terrigenous calcarenites [10]. The Subappennine Clay Formation and

terraced regressive deposits occur on top of the calcarenites (Fig.1). Calcarenite di Gravina can be subdivided in two informal members [14]. The lower member is mainly lithoclastic, having clasts derived from erosion of Cretaceous limestone, and is composed of accretional units bounded by erosional surfaces. These units are stacked in a backstepping configuration, onlapping onto the underlying Cretaceous rocks, and are interpreted to record a punctuated transgression onto the Matera paleo-island as result of the regional subsidence of the Apulian foreland. The upper member is predominantly bioclastic and represents the downslope accumulation of skeletal debris produced within a platform environment, resulting from the partial submersion of the Matera paleo-island. This carbonate-dominated system was subsequently drowned by Pleistocene siliciclastics derived from the erosion of the Apennines thrust belt [7]. The areal facies distribution was controlled by the paleotopography of the Cretaceous substratum [15,16].

Ancient parts of the Matera town, and especially the Sassi, are dug and built in the left flank of the Gravina valley. Here, both members of the Gravina Calcarenites, with predominance of the bioclastic member, crop out. Sassi are subdivided in three main districts: Sasso Barisano, Civita and Sasso Caveoso. The first two are built and dug inside to the bioclastic member of calcarenites while the Sasso Caveoso is mainly inside to the lithoclastic member, characterized by a typical microconglomeratic interval.

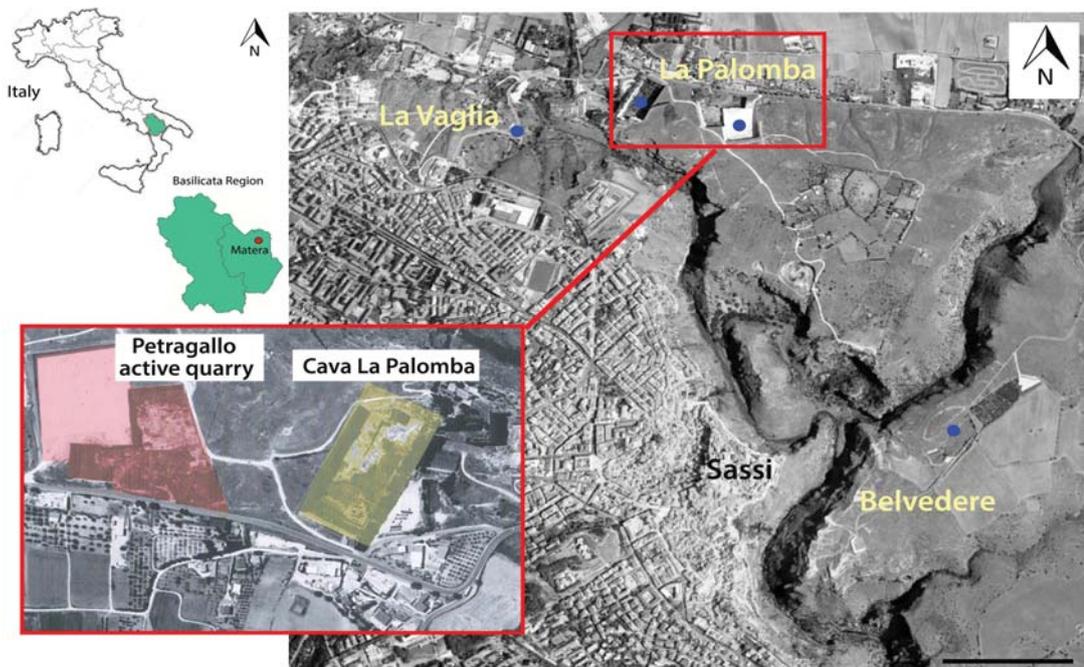


Figure 1- Localization of sampling point in blue with detail of the two quarries where great number of samples have been taken in Matera area (Southern Italy)

### III. SAMPLING AND METHODS

Thin sections have been prepared in the laboratory of the GeoZentrum Nordbayern in Erlangen, Germany, in order to perform petrographic observations by optical microscopy. Petrographic analysis was made with an optical microscope for a textural description and for the qualitative and quantitative determination of the composition.

Sampling for XRD analyses has been carried out in the northern area of Matera, in the quarries area of La Vaglia and La Palomba). Thirteen samples for petrophysical analyses have been selected after detailed macro- and microscopical characterization.

XRF analyses have been performed on bulk samples, to obtain the major element composition while XRD has been performed on bulk samples with an automatic diffractometer with Bragg-Brentano geometry. Petrophysical analyses have been carried out according to the procedures described in several works about characterization of soft limestone [1, 17], according to European Standard rules (EN 1936. to EN 1925, EN 13755 and EN 1926) [18-21]. Analyses have been performed in the Applied Mineralogy Laboratory of the Pisa University and at the above mentioned GeoZentrum in Erlangen).

### III. IV. RESULTS AND DISCUSSION

The Calcarenite di Gravina shows different petrographic features as evidenced by variations in the percentage of components. The analysed calcarenites show different petrographical and compositional characteristics with respect to the amount of lithoclasts and bioclasts, as confirmed by the description of the six lithofacies (Fig.2). Lithoclasts derive from the Cretaceous Altamura limestone while bioclasts in the calcarenites include mollusk shells (pecten, oysters, barnacles, brachiopods), *Ditrupa*, echinoderms, bryozoans, red algae (rodoliths), and benthic and planktic foraminifera. Porosity is inter- and intraparticulate, and also a moldic type is recognized in all lithofacies in variable percentage [11,12,13]. XRD analyses show roughly the same mineralogical composition for whole facies. Calcite ( $\text{CaCO}_3$ ) is the main mineralogical phase (> 95 wt%), as confirmed by calcimetric analysis that present a content of calcium carbonate from 95 to 99% and by literature data [1]. Small amount of quartz, feldspars and phyllosilicates are also present. The chemical compositions of the analysed samples are in agreement with the mineralogy. Several differences have been observed looking at the facies. Based on physical properties, it is possible to subdivide the six facies into three groups: the first includes the basal calcarenite, the calcirudite-microconglomerate calcarenite and the rodolith calcarenite that are not really used as building stones and that present low coefficient of water absorption, low porosity and high cementation.

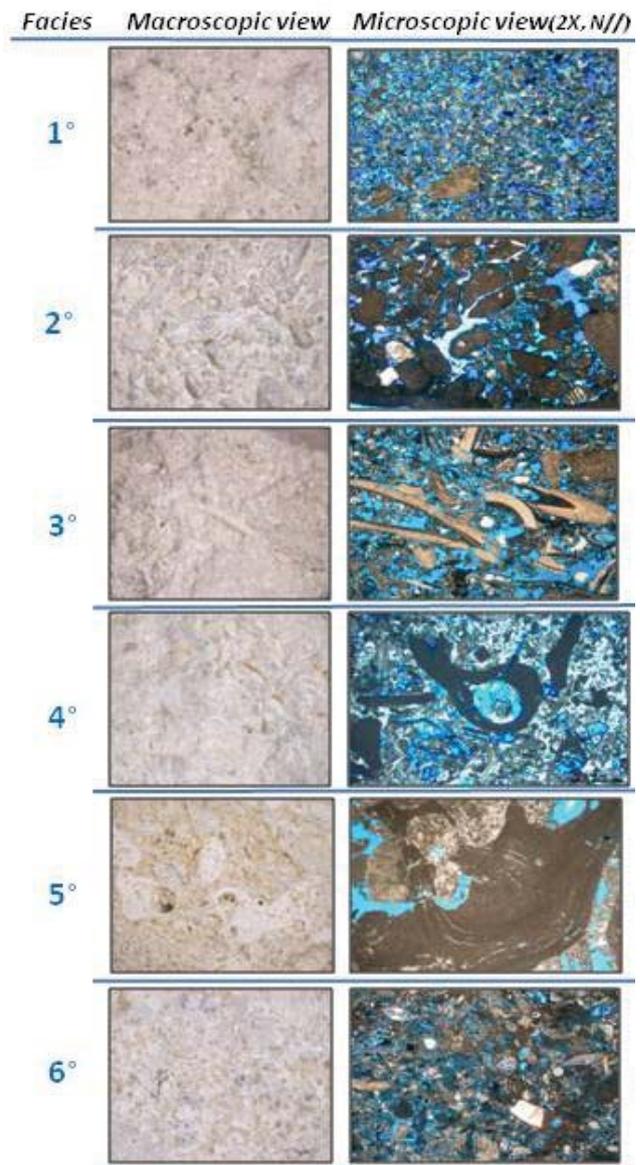


Figure 2 – Six lithofacies recognized into the Calcarenite di Gravina Formation at the mesoscale and in thin section made with blue epoxy resin, at the optical microscope (2,5X, nicols //)

The second group is represented by Facies 3 and 4, corresponding to the lithoclastic and the large bivalve bioclastic calcarenites, respectively. These two groups are widely used as building stones and can be differentiated by the water absorption by capillarity. The lithoclastic calcarenite has a high range of water absorption, responsible for its attitude to include water quickly [11]. Facies 6 represents the third group because its different behaviours with respect all other typologies of calcarenites. Water absorption and water retention is very high, as well as its variability in cementation and porosity due to the intense bioturbation.

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