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Romanesque and Territory

The construction materials of Sardinian Medieval churches: new approaches to the valorisation, conservation and restoration

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Abstract: This paper is intended to illustrate a multidisciplinary research project devoted to the study of the constructive materials of Sardinian Romanesque churches during the *Giudicati* period (11th -13th centuries). The project focuses on the relationship between a selection of monuments and their territory, both from a historical-architectural perspective and from a more modern perspective addressing future restoration works. The methodologies of the traditional art-historical research (study of bibliographic, epigraphic and archival sources, formal reading of the monuments) are flanked by new technologies: digital surveys executed with a 3D laser-scanner, analyses of the materials (stones, mortars, bricks) with different instrumental methods: X-ray fluorescence (XRF) and inductively coupled mass spectrometry (ICP-MS) for chemical composition, X-ray diffractometer (XRD) to determine the alteration phases (e.g., soluble salts), optical microscopy and electronic (SEM) to study textures, mineral assemblages and microstructures, termogravimetric/differential scanning, calorimetric analysis (TG/DTA) for the composition of the binder mortars. This multidisciplinary approach allows the achieving of important results in an archaeometric context: 1) from a historical point of view, with the possible identification of ancient traffics, trade routes, sources of raw materials, construction phases, wall textures; 2) from a conservative point of view, by studying chemical and physical weathering processes of stone materials compatible for replacement in case of future restoration works. Sardinian Romanesque architectural heritage is particularly remarkable: about 200 churches of different types and sizes, with the almost exclusive use of cut stones. Bichromy or polychromy, deriving from the use of different building materials, characterizes many of these monuments, becoming also a vehicle for political and cultural meanings. The paper will present some case studies aimed to illustrate the progress of the project and the results achieved.

Keywords: Romanesque Architecture, Sardinia, Petrographic characterization, Physical features, Mortar, Cut-Stones, 3D Laser scanner

Introduction

The study here presented is a multidisciplinary research-project involving two departments (Chemical and Geological Sciences Department and History & Cultural Heritage Department) of the University of Cagliari (Italy) and the Institute of Atmospheric Sciences and Climate, part of the Italian National Research Council

(C.N.R.). The project focuses on the relationships between medieval monuments and the territory they belong to from a double point of view: i) a historical perspective aiming to collect new data for historical studies and to obtain a better knowledge of the monuments, information and archival data (COLUMBU and VERDIANI 2014) on the ancient quarries originally used for the extraction of the building materials; ii) a present-day perspective aiming to define the physical and mineral-petrographic characteristics of the geomaterials (stones, mortars) in order to find: ii1) the exact provenance of the stones used in the monuments grounding on a geochemical and petrographic base (COLUMBU et al. 2014); the raw materials used for the monuments investigated; ii2) the correct chemical products for future restoration works and for the conservation of geomaterials. Detecting the ancient quarries originally used for the extraction of geomaterials also means to be able to test the chemicals on the same materials that will be used in the monuments, and also to replace the ashlars of altered and degraded lithologies with similar ones. The research group has selected twenty case-studies. They are all Romanesque churches (mainly dating late 11th - early 13th c.) of various dimensions and construction materials, exclusively built with cut-stones.

Historical context

Our research project concerns a very particular historical context, whose political and cultural features have to be considered before any deeper analysis. Sardinia during the Romanesque period was divided into four different kingdoms, called *Giudicati*: Cagliari, Arborea, Logudoro and Gallura.

Each of them had a local dynasty of *iudices*, whose authority was a local evolution of a Roman-Byzantine structure of government, affected by a long period of isolation and distance from the imperial capital. For the 13th century written records enable us to draw a map of the administrative districts of the *Giudicati,* called *Curatorie*.

The crucial – albeit very far – link with the Roman tradition provided the *Giudicati* with a sharp sense of the public rule even in managing materials and buildings: there is no evidence of the general evolution of *incastellamento* in Sardina before the arrival of Genoeses and Pisans, and therefore stone buildings were very often directly supported by sovereign authorities.

The second feature we need to consider is the importance of Tyrrhenian cities, Genoa and Pisa and their relations with Sardinia starting from the mid-11th century. While the two maritime communes found in Sardinia many opportunities of colonial power, the *iudices* borrowed from outside a language of political pre-eminence. Barisone d'Arborea, for example, obtained from Genoa and the emperor Fredrick I the title of king of the whole island; in the very same period, Logudoro deepened its relations with the Cistercian order in France, Italy and even in Holy Land. In the 13th century, starting from the southern *Giudicato* di Cagliari, Tuscan feudal families succeeded in taking control of Sardinian territories, and therefore they created Tuscan dynasties on former Sardinian *Giudicati*. In that context, they tried to use local traditions to strengthen their prestige, but at the same time they shared with the Tuscan or Genoese lords a common language of artistic patterns, in order to be accepted in a broader range of Mediterranean powers. Within such a cultural exchange, the building of churches was one of the strategies used by the *Giudici* to emphasize their authority: we have also to take into consideration the fact that supporting new monastic or

religious building was a message sent to the Popes, that confirmed the Catholic identity of the *Giudicati* after many centuries of theoretical link with Byzantium.

These different features we have outlined had a very strong effect on Sardinian architecture. First of all, churches and religious buildings were very often promoted by royal powers: or at least, religious communities were supported by *iudices* in their Sardinian settlements in order to give prestige to local dynasties. On the other hand, religious communities usually arrived from outside the island (Benedictins from central Italy, Camaldulese and Vallombrosan communities from Tuscany, St. Victor monks from Marseilles, Cistercians from northern Italy and France) bringing their own building traditions. As a result, foreign models played a major role in shaping the Sardinian architecture as well as the strategy of symbolic communication of *iudices*. It is, in a sense, a particular case of the broader problem of re-using ancient or foreign materials in medieval art and culture.

Choosing materials for ecclesiastic and monastic buildings was a matter of material possibilities (distances and transport availabilities, technical skills of managing different kinds of stones), but at the same time it depended on symbolic strategies. Among the material possibilities it is important to include the existence of rich stone quarries in several areas of the island: basaltic rocks, sandstone, granite, even not considering the remains of ancient buildings with their marble materials. In a very general sense, such a material opportunity had a direct effect on architectural choices in different areas of the island; apparently, in neighboring areas the use of materials was not qualified by 'state' traditions and identities, rather it depended on the availability of the stones. From a first survey on general figures, therefore, we have to assume a high degree of imitation between the *giudicati*, in order to adjust artistic languages to particular material patterns.

Our project aims to go beyond such a general impression, by investigating the possibility to link special kinds of stones in church sites with particular quarries around the country, in different *Curatorie* or even in different *Giudicati*. Did the *iudices* and their monastic communities use just the closest quarry, and by consequence adjust their local ambitions to material possibilities? Did they try to find their favorite cut-stones even outside the local spaces in order to imitate their foreign models or improve the effectiveness of artistic communication? The question is even more complex concerning the several cases of religious building where two or more different kinds of stone were used. In that case, it is not likely that the use of different stones depended only on practical reasons, first of all because bichromy was a typical feature of Tuscan architecture.

To answer to such a question could suggest us how far could the *iudices* look for by conceiving their artistic aims. The importance of the particular approach of our study lays on the fact that written records do not allow for 12th, and mostly even for 13th century, to analyze the internal relations between the *Giudicati* as an economic problem: as a consequence, written records do not help us to understand the very sense of the glorious period of Romanesque buildings in Sardinia. The use of material evidence and the study of the different kind of stones could give us a new possibility to consider our few documentary figures, and to deepen our understanding of political, economic and cultural history of medieval Sardinia.

Romanesque architecture in Sardinia

Romanesque churches, built between 11th and 13th century, during the age of the *Giudicati*, represent one of the best preserved part of the Sardinian artistic heritage. This is due to many factors: more than 180 churches, mostly rural, showing at least an important Romanesque phase, still survive; all but two are built using exclusively cut-stones; most of them are very well preserved because of the absence of seismicity in Sardinia, but also because of the lack of major works of restoration/alterations in the subsequent centuries (only during the late 19th c. - early 20th c. the new interest for the Middle Ages has led to several restoration with frequent replacements of cut-stone ashlars with new ones of different kind) (DELOGU 1953; CORONEO 1993; CORONEO & SERRA 2004).

During the age of the *Giudicati*, the wide diffusion of the Romanesque architecture all over Europe, paired with the rebirth of large-scale trades connecting the Mediterranean shores, led to the building of a large number of Romanesque churches imitating various models locally declined in different ways. Workshops came to Sardinia from overseas (Tuscany, Lombardy, France, North Africa) and worked in the building sites together with local masters and workforce. This impressive architectural heritage is very well preserved still nowadays and it is basically intact.

Operative activities and methodological approach

The research project is structured in three major phases for a three years duration: 1. Survey; 2. Physical and minero-petrographic characterization of geomaterials; experimental laboratory test on geomaterials with chemical products; 3. Creation of a scientific-analytical database useful for future restoration works.

Survey

The survey phase consisted in the selection of twenty monuments. The selected monuments have been studied using the criteria of the historical, archaeological and art-historical research: detection and study of archival, epigraphic and literary sources, historiography and critical literature, formal and stylistic reading. These research phases have led to a complete reading of the monuments with a detection of the different constructive phases.

At the same time, the research unit of art-historians, historians and archaeologists is supplying data deriving from the old and new excavations in the churches and in the areas around the monuments. Under investigation are especially the medieval villages now disappeared (most of them abandoned after the Catalan conquest of Sardinia, in the early 15th century). Historians and archaeologists are also reconstructing the relationships between territories and villages by highlighting the role and the interrelations of ancient roads, cathedrals, abbeys and parish churches in a specific territory; the role of the itinerant residences of the *giudici* (the local kings), who were also the patrons of many of the churches investigated.

A second step in the survey phase consisted in the application of the scientific research method to the selected monuments: sampling and characterization of the lithotypes (stones, mortars); detection of the state of preservation and the causes of decaying of the construction materials (CORONEO and COLUMBU 2010).

Physical / mineral-petrographic characterization of geomaterials and their provenance

The second phase, characterization of geomaterials, consists in defining the geochemical and minero-petrographic characteristics of the stones sampled on the monuments selected. The petrographic characteristics (texture, microstructure, etc.) are determined with optical microscope, while XRF (or ICP-M) and XRD analysis will determine the chemical composition and the secondary phases, respectively. These investigations are made on the samples obtained from the monuments and from the rock outcrops that show similar characteristics with the stones used in the monuments.

It becomes thus possible to find the original ancient quarries by comparing the geological knowledge of the territory with the results of the archival and bibliographic research. The investigations made in the archives of the local *Soprintendenze* (Italian bureaus for the preservation of monuments and cultural heritage) are supplying important data related to the old restoration works (late 19th - first half of the 20th century until World War II) when restorers and architects tried to detect the original quarries used in medieval times in order to obtain building materials as close as possible to the originals for what concerns colour, grain, structure. In many cases, during these works of restorations, large amount of ashlars have been replaced; thus restorers, for obvious reasons, needed cut-stones which could camouflage with the original (even if in many cases they deliberately let evidences of the substitutions they made). The findings deriving from the archival research, when compared with the petrographic analysis of stone materials deriving the samplings in the churches and in the quarries around the monuments are starting to supplying important, though still partial, results (the work is still in progress): in many cases the original quarries appear to be the same detected by the old restores in late 19th - early 20th century.

The characterization phase of geomaterials also consists in the study of alterations and decay of materials and structures due to ancient restorations, in order to conduce a complete reading of the monuments and their construction and re-construction phases until our days. Investigations also concern the work in medieval constructions sites: starting from the few sources still existing (mainly epigraphs preserved in the monuments mentioning the patrons and/or the main master, the architect), it will be better defined the role of *magistri*, stone-masons and other medieval workers.

The last step of the classification phase is the creation of a 3D laserscan relief of each monument, a specific tool which will help the reading of the mural stratigraphies and the volumes of the buildings.

Over two-thousand micro-samples of natural stones and mortars, belonging to thirteen Romanesque churches, were collected indoor and outdoor on the exposed faces of monuments, and studied to acquire data on physical-chemical properties of building materials. To minimize damages, micro-samples were collected in areas where the stones are already partly detached from the substrate. Additional micro-sampling of altered materials (newly-formed minerals and soluble salts), occurring as alterations on the natural stones and mortars, was performed indoor and outdoor on the exposed faces of the monuments. Samples were geo-referenced and digitalized by a laser scan survey.

Analytical studies are essentially aimed at acquiring data on physical features and chemical composition of both original materials and their degradation products. But, for an appropriate selection and application, the investigations, focused to the acquisition of physical-chemical data of monumental structure components, were preliminarily projected and planned. In effect, the correct formulation of a diagnostic protocol has to

allow to identify i) nature and texture of decay materials, ii) causes of the alteration, and iii) physical-chemical agents responsible of decay.

The following methodologies, considered non-destructive (or para-destructive) techniques for the minimum amount of sample required to carry out analyses, were used for a complete physical characterization of materials from the Romanesque churches and include:

- ✓ Optical Microscopy, providing data on mineral phase composition and textural parameters belonging to natural rocks and/or other solid materials;
- ✓ Thermal analysis (DTA, TG, DTG), essential for the characterization of chemical compounds present in the degradable mortars and plasters. Useful information on the composition of the materials can be acquired from the weight loss, a function of temperature. From the quantitative determination of ligand present in the mortar and comparative surveys it is possible to assess, for instance, if a sample is altered.
- ✓ X-Ray Diffraction Analysis (XRD), provides qualitative and quantitative information on mineral composition (crystalline phases) of solid samples, powered for carrying out the analysis. In some cases, even non-crystalline phases, such as glass, can be determined and quantified (e.g., volcanic glass, which represents a major fraction in particular volcanic rocks, as pyroclastites/ignimbrites);
- ✓ Scanning Electron Microscope (SEM) studies, provide information on textural parameters of a sample (fibrous, lamellar, compact, porous morphologies), as well as quantitative chemical analysis on micro-surfaces by the technique known as EDAX microprobe. The SEM techniques also consent the identification and distribution of alteration products of materials (fractures, decohesion), and minerals (desquamation, flaking, etc.), as well as acquire information on structural modifications of materials, all useful data to recognize the agents of decay. Moreover, chemical (EDAX) and structural (SEM) integrated study is an effective approach to determine the relationship between microstructure and chemical composition.
- ✓ X-Ray Fluorescence (XRF), provide quantitative chemical data on the whole sample, for major (wt%) and minor (ppm) elements. In vacuum the analysis consents to detect and quantify all chemical elements from Boron to Uranium.
- ✓ Inductively Coupled Plasma Mass Spectrometry (ICP-MS) is a technique more sensitive (10 ppb) and precise than the XRF. Major, minor and trace elements - from Lithium to Uranium - of solid and liquid materials can be determined.

The macroscopic aspects of stone surface (e.g., micro-morphology) are determined through photogrammetry observations (COLUMBU and VERDIANI 2014), while the physical properties (solid and real densities, bulk density, open and closed porosity to water and helium, saturation index, mechanical resistance, etc.) of the rock or mortar specimens are made according to the following methods: water and helium picnometry, water absorption, hydrostatic balance, hydraulic press machine (with rupture load until 3000 kN).

Creation of a scientific-analytical database for future restorations

The third phase consists in the elaborations of operative indications for future restoration works of the monuments studied (e.g. supplying materials useful for tests of compatibility with products used in

restoration; locating the quarries used in medieval times for future restoration works intending to substitute the damaged ashlars with new ones).

Discussion of results

Use of geomaterials in the monuments

One of the most evident features of Sardinian Romanesque architecture is a large use of various stones with different colours and compositions in order to obtain a chromatically rich exterior aspect. Very commons are the so-called banded architectures where the use of building materials of two different colours (usually a bright one and a dark one: black (i.e., basalts) and white (i.e., limestones), brown (i.e., ignimbrites) and white, red (i.e., ignimbrites) and white, green and white) creates a strong contrast which animates exterior walls and interior spaces. This solution has usually been reconnected to the model of the cathedral in Pisa which, in turn, would have drawn these decorative patterns from the Islamic mosques in the Eastern Mediterranean, according to the reading commonly accepted by the critics (TIGLER 2006). Even if Pisa ever had this role as a transmission wheel - as it is likely - it is indeed very difficult to connect to the same root many different monuments like the mosque in the Damascus to the church of St. Madeline in Vezelay (France), the mosque in Cordoba to the churches in Tuscany (Florence, Pisa, Pistoia among the many others), Campania (Amalfi cathedral), Sardinia and Corsica.

The Mediterranean and Oriental fascination was probably only one of the many reasons.

The research group is also investigating to what extent the availability of materials influenced architectural aspects, by detecting how difficult and expensive was to build a church in *two-colours* and to what extent, instead, this was a specific choice due to aesthetic, political, theological reasons.

Three case-studies are here presented: the Trinità di Saccargia abbey (12th century) (Fig. 1), located in north-western Sardinia, *giudicato* of Torres, in medieval times. The abbey has been built in two different phases: the first one after 1116 (three apses and part of the nave) and the second one in the late 12th century (nave, façade, portico and bell-tower) (CORONEO & SERRA 2004). The materials originally used were a local limestone and basalt. These materials had different resistance to load and weathering (Fig. 2), clearly legible now. The church was interested by some *aggressive* late 19th century and 1930 restorations which consisted in frequent replacement of ashlars, sculpted capitals and friezes (Fig. 3), and the columns in the portico (Fig. 4); also, a mullioned window replaced an original round window in the façade and the dimensions of the portico changed too: the original was higher.

Fig. 1 – Trinità di Saccargia abbey

During these works the original bright stone (limestone) has been frequently substituted with granite (a stone not belonging from the region) (GIZZI 2007) because of structural reasons. Probably, crystalline limestones coming from quarries in southern Sardinia (Teulada) not in use in medieval times have been used for the substitution of the figured capitals.

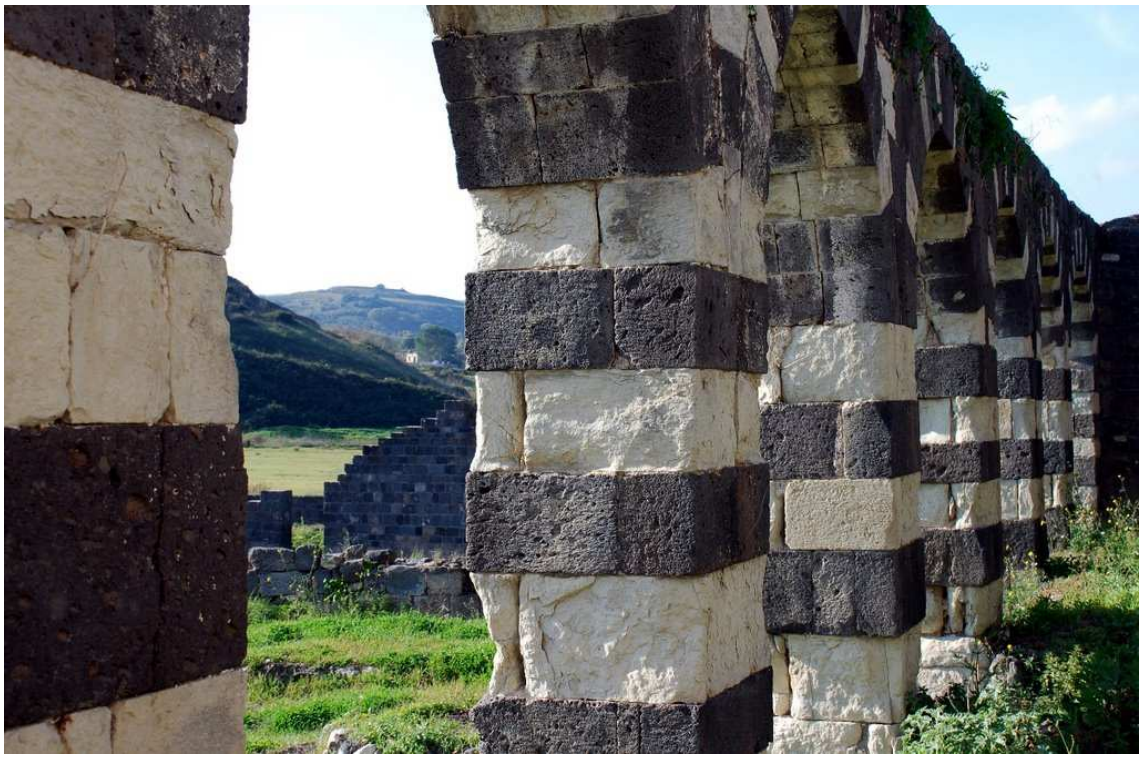

Fig. 2 – Trinità di Saccargia abbey. Arches of the remaining structures of the monastery. It is clearly legible the different resistance to load of limestone and volcanic ashlars

The research group is currently trying to detect, beside the original limestone quarry, another quarry whose material, similar for composition, colour, physical and petrographical features, is more resistant to load than the original one and can be efficiently used in case of future restorations.

Another case study here presented is the cathedral of S. Pietro di Sorres (north-western Sardinia) (Fig. 5), built in the second half of the 12th century (CORONEO & SERRA 2004). Here, bichromy was chiefly used in the interior space where it clearly marks the shafts of the pillars with its typical horizontal stripes, but it also characterizes the vaults (black basalts) and the walls (white limestones), in a space modeled by the light coming only from small windows (Fig. 6). Here, the aesthetic of light, and the contrast of light and darkness, so important for the Cistercians, might have played an important role in the definition of forms and colours (hence materials) used to rebuild and enlarge the church in the second half of the 12th century.

A series of Cistercians monks called directly from Clairvaux administered the cathedral as bishops for many decades in the second half of the 12th century, and they likely organized the reconstruction of the cathedral in the present-day forms, under the direction of a possible Sardinian master who left his name carved in one of the step by the main door (Fig. 7).

A third case, the church of S. Pietro delle Immagini near the village of Bulzi (12th c.) (CORONEO & SERRA 2004; PALA 2012) (Fig. 8), shows a large use of the bichromy (ignimbrites and limestones) in the façade and in the apsidal conch, in the interior (Fig. 9). This last example shows that if the symbolic hearth of the church, the apsidal conch, was meant to be left without a painted decoration but with the striped pattern in full view, there might have likely been symbolic and theological reasons behind this choice, other than a simple replication of a given model widely circulating in 12th century Sardinia.

Fig. 3 – Trinità di Saccargia abbey. Detail of the sculpted frieze on an arch in the portico. The right part (both the ashlars and the frieze) has been substituted and recreate during late 19th century restoration works.

Fig. 4 – Trinità di Saccargia abbey. The western portico, with late 19th century granite columns which replaced the original limestone ones.

Fig. 5 – S. Pietro di Sorres, interior.

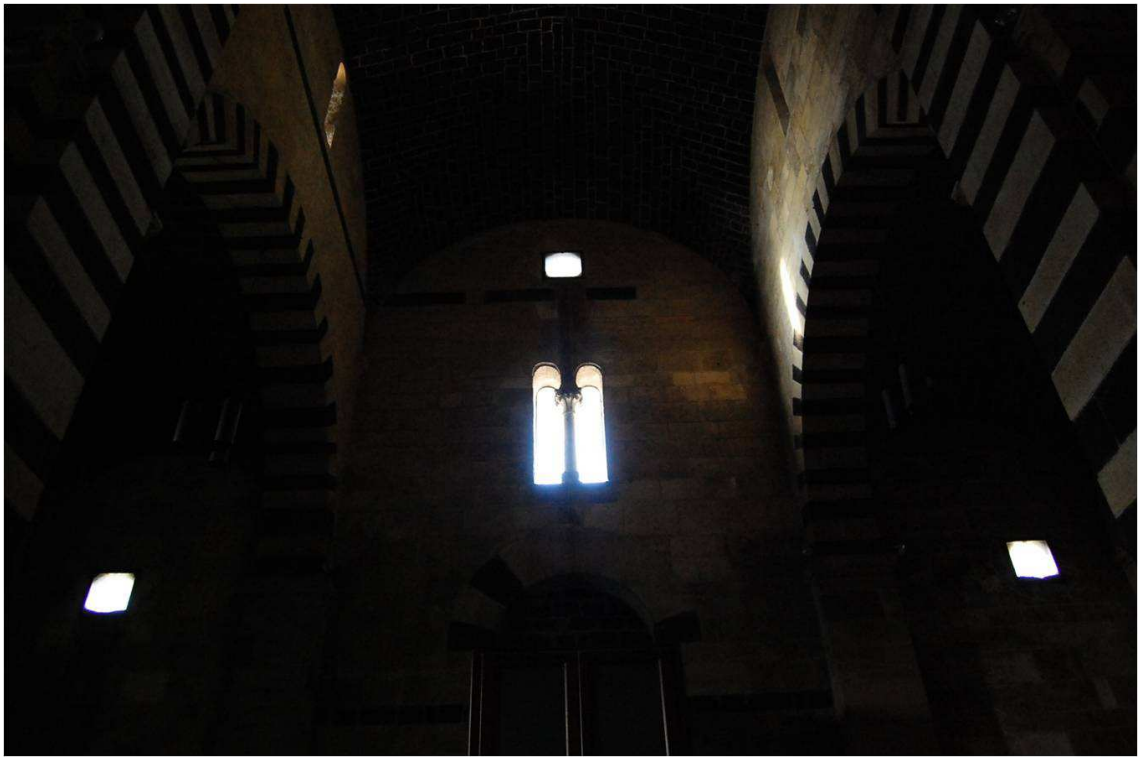

Fig. 6 – S. Pietro di Sorres, interior.

Fig. 7 – S. Pietro di Sorres, 12th century epigraph mentioning *MARIANE MAISTRO.*

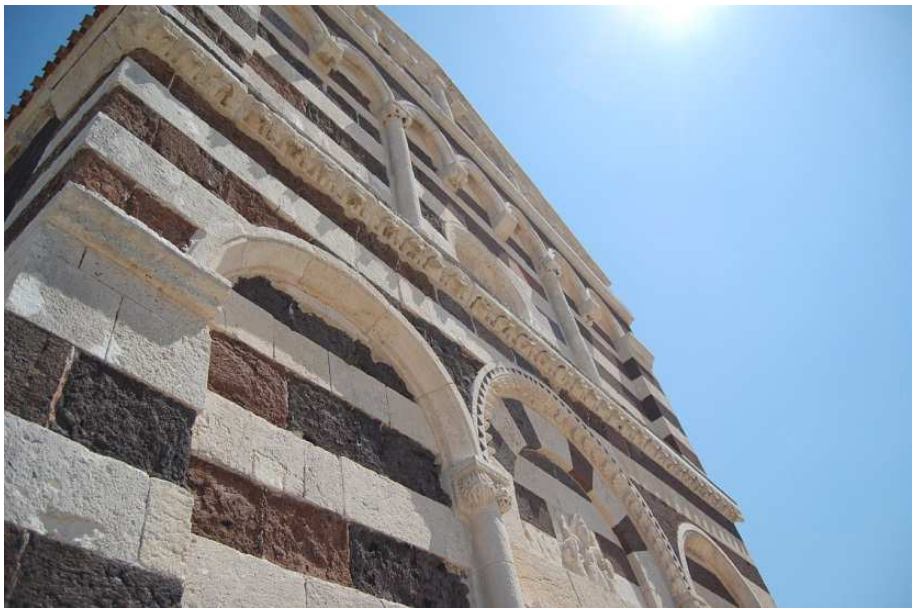

Fig.8 – S. Pietro di Bulzi, façade.

Fig. 9 – S. Pietro di Bulzi, interior.

Relations between architectures, geomaterials and territory

Another task of this project is to compare the map of the *Giudicati* with the territorial distribution of construction materials and the related churches. Were there a link between construction materials and the *identity* of each of the four kingdoms (e.g. the *giudicato* of Gallura and granitoid rocks).

The variety of cut-stones used in the churches is an important feature of the monuments studies. Variety is of course due to the different distribution of materials in the Sardinian territory and to its diversity: granite is largely diffused and employed in the region of Gallura (North-eastern Sardinia), mainly limestones and pyroclastites in the North and North-western part of the island; the basalts are the common materials present in the central-north Sardinia and in central volcanic plateaus (COLUMBU *et al.* 2011) of island; sandstones and limestones are more diffused in the South.

Conclusions

The research units have already gathered information about the building materials used in twenty Romanesque Sardinian churches selected as case-studies. Analysis on the data collected are now supplying information about the petrographic and physical features of the stones and their chemical-physical decay, the provenance of raw materials, the use of different stones as meaningful materials related to the territory and their peculiar history in order to detect any possible use of a specific stone for reasons different than the sheer availability (i.e. identity, historical links with previous eras, iconology of the materials) physic-static conditions of the monuments.

The archival analysis are now identifying which specific stones in any specific monument have been replaced during the late 19th-20th century restorations and which parts of the monuments are supposed to keep the original materials. The 3d laser-scan reliefs of the monuments will supply new possibilities to read and understand the monuments and the connections with the information deriving from the study of geo-materials will help to better understand the different building phases of each monument.

The data collected and studied will also help us to update the specific terminology of cut-stones used in art-history literature, still linked to an old 19th century terminology. The final results are also expected to be of big help to understand the medieval work in quarries and building sites with the help of the archaeological excavations currently underway in many medieval villages of the island - now abandoned - and in the former monasteries or episcopal residences around the churches.

All the data, once collected in a scientific database will be an important tool for future restoration works in case it will be needed to replace the old damaged ashlars with new ones.

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activities and methodological approach: Survey; *Discussion of results: Use of geomaterials in the monuments*; *Relations between architectures, geomaterials and territory*.

References

COLUMBU, S., GIONCADA, A., LEZZERINI, M., MARCHI, M. (2014) Hydric dilatation of ignimbritic stones used in the church of Santa Maria di Otti (Oschiri, northern Sardinia, Italy). Ital. J. Geosci. (Boll. Soc. Geol. It.), Vol. 133, 1, 149-160.

COLUMBU, S., VERDIANI, G. (2014) Digital Survey and Material Analysis Strategies for Documenting, Monitoring and Study the Romanesque Churches in Sardinia, Italy. Digital Heritage. Progress in Cultural Heritage: Documentation, Preservation, and Protection. Lecture Notes in Computer Science, Springer, Volume 8740, 2014, pp 446-453. DOI: 10.1007/978-3-319-13695-0_43. ISSN: 0302-9743.

CORONEO, R., COLUMBU, S. (2010) Sant'Antioco di Bisarcio (Ozieri): la cattedrale romanica e i materiali costruttivi. Archeoarte, vol. 1, 145-173.

COLUMBU, S., GARAU, A.M., MACCIOTTA, G., MARCHI, M., MARINI, C., CARBONI, D., GINESU, S. & CORAZZA, G. (2011) Manuale sui materiali lapidei vulcanici della Sardegna Centrale e dei loro principali impieghi nel costruito. Ghilarza: Iskra.

CORONEO,, R. (1993) Architettura romanica dalla metà del Mille al primo '300. Nuoro: Ilisso.

CORONEO, R. (2001) 'L'irradiazione delle maestranze della clesia nuova di Sanata Maria di Bonarcado nel giudicato di Arborea', in Giudicato d'Arborea e Marchesato d'Oristano: proiezioni mediterranee e aspetti di storia locale. Conference proceedings, Oristano, 5th - 8th December, ed. by G. Mele. Oristano: Istar, pp. 463-485.

CORONEO, R. & SERRA, R. (2004) Sardegna preromanica e romanica. Milano: Jaca Book.

DELOGU,, R. (1953) L'architettura del medioevo in Sardegna. Roma: La libreria dello Stato.

FRANCHETTI PARDO, V. (2001) Città, architetture, maestranze tra tarda antichità ed età moderna. Milano: Jaca Book.

GALLINARI, L. (2010) 'Il Giudicato di Calari tra XI e XIII secolo. Proposte di interpretazioni istituzionali', RiMe – Rivista dell'Istituto di Storia dell'Europa Mediterranea, n. 5, pp. 147-187.

GIZZI, S. (2007) SS. Trinità di Saccargia. Restauri (1891-1897). Roma: Gangemi.

Ideologie e pratiche del reimpiego nell'Alto Medioevo 1998. Settimane di studio del Centro italiano di studi sull'alto medioevo, 46. Conference proceedings, 16th - 21th April 1998. Spoleto: CISAM.

PALA, A. (2012) San Pietro del Crocifisso a Bulzi: architettura e arredo sacro della chiesa romanica. Preface by Rossana Martorelli, Ghilarza: Iskra.

PETRUCCI, S. (1988) Re in Sardegna, a Pisa cittadini: ricerche sui domini Sardinee pisani. Bologna: Cappelli.

SOMMA, M.C. (2010) Cantieri e maestranze nell'Italia medievale, Conference proceedings, Chieti-San Salvo, 16-18 maggio 2008. Spoleto: CISAM.

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