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The stones of the Svevian castle of Rocca Imperiale (Calabria, southern Italy): characterization and provenance

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Abstract. — The Svevian Castle of Rocca Imperiale (north-eastern Calabria, southern Italy) was built between 1220 A.D. and 1225 A.D. by the Emperor Federico II of Svevia. This paper addresses the geochemical and petrographical characterisation of the stones used for its construction. The research evidenced that most of the Castle stony materials (marly limestones, calcareous marls, marls, arkoses and quartz arenites), were carved from siliciclastic outcrops nearby Rocca Imperiale. Stones from outer areas are more rare (biocalcarenites). These stones probably come from the nearby Puglia region and were mainly used for decoration.

Riassunto. — Il castello di Rocca Imperiale (Calabria nord-orientale, Italia meridionale) è stato costruito tra il 1220 e il 1225 dall'Imperatore Federico II di Svevia. Il presente lavoro riguarda la caratterizzazione geochimica e petrografica delle pietre utilizzate per la sua costruzione. Lo studio ha messo in evidenza che la maggior parte dei materiali lapidei (calcari marnosi, marne calcaree, marne, arkose e quarzo areniti) del castello provengono dai terreni flyschoidi di Rocca Imperiale. Più rare sono le pietre di origine non locale (biocalcareniti), utilizzate prevalentemente con finalità decorative e la cui provenienza è da ricondurre, con molta probabilità, alla vicina Puglia.

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Key Words: *siliciclastic outcrops, quarries, marly limestones, calcareous marls, marls, arkoses, quartz arenites, biocalcarenites, raw materials.*

Introduction

The Svevian Castle of Rocca Imperiale (Fig. 1), placed near the border between the Calabria e Basilicata regions (Southern Italy), is by far one of the most important Calabrian monuments, due to its geographical position, dimension and history.

The building, ordered by the Emperor Federico II of Svevia, was constructed between 1220 and 1225 (Fiore, 1989). The architect Nicolò De Cicala (Fiore, 1989) probably indicated the exact place where it was built. In fact, for strategic reasons, the Castle foundations were made on a 200 m high hill. During many centuries the Castle underwent many architectonic changes due to the many military sieges its structure had to face. We can remind the attack by "Carlo lo Zoppo" in 1296 during the Aragon's domination and the many attacks by the Turkish in the course of the XVI century. The Svevian owned the Castle up to 1266; after that, it went under the Angevin domination which lasted about 170 years. Successively, the Castle was dominated by the Aragons up to 1503. From that day the castle was sold and bought back for several times and at the present it is patrimony of the local municipality.

Fig. 1 – Rocca Imperiale Svevian Castle: a) North view; b) Castle front door.

At present, there are neither archaeometric published studies about the castle nor detailed studies aiming to clarify the composition and the provenance of the materials used for its construction; for this reason, this work – which derives from a previous study carried on all the castle stony natural and artificial materials (Miriello, 2005) – is oriented to shed a light on composition and provenance of the stony material used for its construction.

Sampling and geology

The construction of the castle has been facilitated by the availability of stony material in the neighbourhood. The fields around Rocca Imperiale are often disseminated with piles of stones, even large sized ones, which peasants have patiently piled up in order to reclaim the ground and make it easy to be worked on by their agricultural tools. The siliciclastics outcrops in most of the study area are characterized by diverse types of rocks, in the shape of blocks potentially fitting for building purposes.

All the rock types in the castle walls, which were distinguished for macroscopic characteristics, have been sampled. Thus, 20 samples from the castle inside rooms were taken. They were labelled by an identification mark "Rri", followed by a sampling progressive number. It wasn't difficult to take the samples out of the walls since many of them have tumbled down. To find out the areas where the raw material were taken by the ancient builders, many reconnaissance have been made on a 20 km^2 area and 18 samples representative of the different typologies, macroscopically similar to those of the castle, have been taken. Such samples were labelled by the identification mark "Cav".

Figure 2 shows both the location of the outcrops out of which stony materials were taken and the identification marks of the diverse samples.

Rocca Imperiale territory is mostly characterised by siliciclastic rocks, which belong to the "*Unità Sicilidi*" (Ogniben, 1969). These terrains were involved in overlapping processes during the late phases of the Calabrian arc construction and generated some tectonic overthrusts. One of these geologic units known as *"Rocca Imperiale overthrust"*, forms the geological framework of the studied area. The "Rocca Imperiale overthrust" is covered by Plio-Pleistocene sedimentary rocks (Ghezzi, 1973). The sequence (Fig. 2) comprises a shale and siliciclastic calcareous unit made up

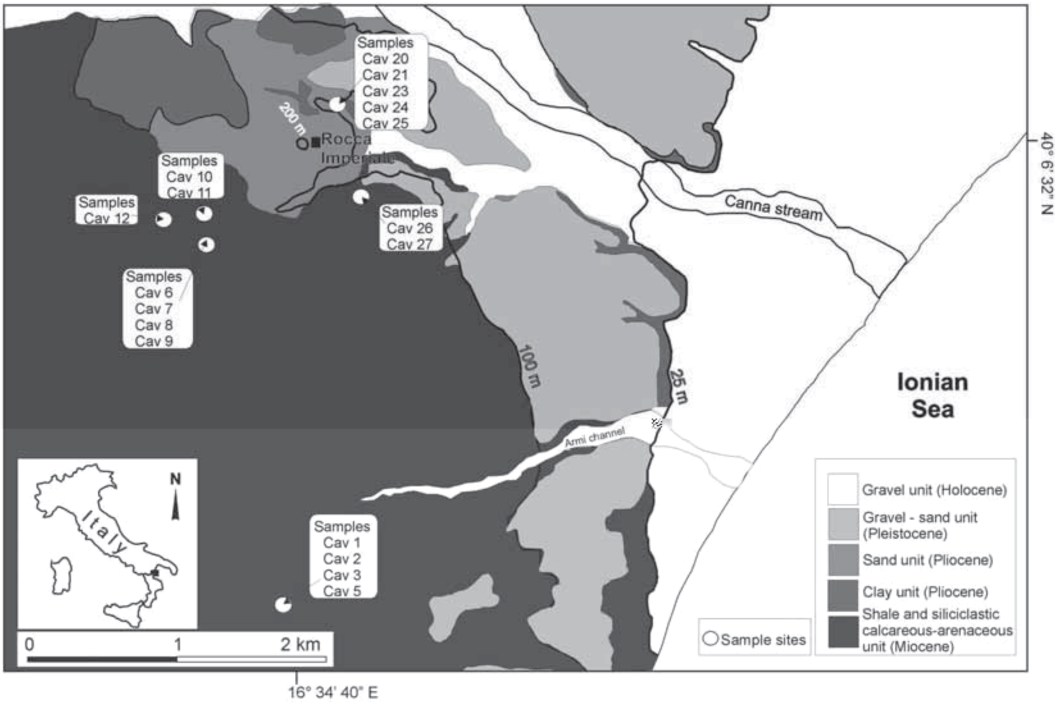

Fig. 2 – Geo-lithologic sketch map of the studied area with the sample sites.

of clays, shales, limestones (varying from marly limestones to marl), arkoses, quartz-arenites, with intercalations of calcarenitic layers. Pliocene deposits (grey-blue clays and stratified yellowy sand) unconformably overlie the shale and siliciclastic calcareous unit. Pleistocene deposits transgressively overlie all previously described rock types. They are made up of incoherent conglomerate, mixed to coarse-grained sand. Gravels and Holocene sands occur along the Canna and Armi drainage basins.

Methods

All the samples were petrographically characterized. The concentration of the major (SiO_2, TiO_2, Al_2O_3, Fe_2O_3, MnO, MgO, CaO, Na_2O, K_2O, P_2O_5) and trace elements (Cr, V, Nb, Ni, Zr, Y, Sr, Ba, Rb, La, Ce, Co) were determined by using a "Philips PW 1480" spectrometer (Scandium/Molybdenum and Rhodium tubes), following the method for correcting matrix effects proposed by Franzini *et al*. (1972, 1975).

The $CaCO_3$ content of all the stony materials was measured by a "De Astis Calcimeter"; calcimetry has been used for classifying the carbonatic rocks (Correns, 1968).

The acquisition of the thin section images with polarised light was obtained by using a flatbed scanner equipped with an appropriate acquisition tool (Miriello & Crisci, 2006).

Results and discussion

Crisci *et al*. (2003) and De Francesco *et al*. (2003) have shown that the petrographic study often allows the resolution of many provenance problems at a first analysis. These observations, combined with the information obtained from chemical analysis (Tab. 1) and by the calcimetry (Tab. 2), supplied a

TABLE 1 – *XRF anhydrous analyses of major* (wt %) *and trace elements* (ppm) *of the stone samples taken from Rocca Imperiale (Rri) castle and from geological outcrops (Cav).*

Samples	Rri 1	Rri 2	Rri 3	Rri 4	Rri 5	Rri 6	Rri 7	Rri 8	Rri 9	Rri 10	Rri 11	Rri 12	Rri 13	Rri 14	Rri 15	Rri 16	Rri 17	Rri 18	Rri 19	Rri 20
SiO2	61.57	8.01	33.80	32.18	35.90	10.01	7.26	5.35	58.28	45.97	10.61	64.79	48.04	19.12	12.85	27.97	5.81	8.11	12.38	7.33
TiO2	0.72	0.14	0.08	0.20	0.08	0.10	0.15	0.11	0.66	0.11	0.13	0.34	0.50	0.11	0.17	0.31	0.08	0.16	0.08	0.08
Al2O3	14.06	1.40	2.71	4.52	1.46	0.79	1.88	1.20	9.58	2.91	1.75	9.08	5.39	1.45	1.99	2.75	0.58	1.59	0.83	0.53
Fe2O3	7.84	3.77	7.56	13.15	6.23	1.20	2.93	3.46	4.31	7.38	2.92	2.55	12.44	3.72	1.54	3.23	0.69	3.37	3.57	2.78
MnO	0.14	0.39	0.52	0.75	0.24	0.11	0.03	0.11	0.10	0.20	0.51	0.14	0.37	0.40	0.73	0.30	0.30	0.12	1.58	0.31
MgO	3.23	1.98	1.90	2.29	1.23	3.19	1.99	3.54	1.80	2.19	1.58	2.29	7.90	1.60	2.29	1.73	2.40	3.44	1.60	1.92
CaO	8.57	84.04	53.05	46.54	54.64	83.49	81.30	85.58	21.97	41.06	81.96	17.47	24.06	73.36	79.89	62.72	89.98	81.88	79.85	86.93
Na2O	1.70	0.07	0.01	0.17	0.05	0.42	0.67	0.17	1.78	0.05	0.20	2.17	0.57	0.10	0.15	0.54	0.08	0.57	0.05	0.08
K2O	2.06	0.14	0.36	0.20	0.17	0.62	1.17	0.28	1.46	0.13	0.31	1.16	0.68	0.14	0.32	0.35	0.07	0.58	0.05	0.05
P2O5	0.12	0.05	0.00	0.02	0.00	0.08	2.61	0.20	0.04	0.00	0.02	0.01	0.04	0.00	0.08	0.10	0.01	0.18	0.00	0.00
L.O.I.	8.40	40.93	31.58	29.50	32.96	41.94	40.23	42.18	15.75	27.03	38.65	14.53	24.29	38.15	40.27	33.17	42.22	42.23	40.35	40.96
Cr	64	9	17	27	17	24	41	21	39	20	12	20	78	16	32	22	19	27	11	9
V	78	17	28	28	16	17	26	34	49	25	20	29	51	7	16	17	7	26	4	11
Nb	14	0	0	3	1	0	2	1	12	1	0	6	7	0	0	4	0	2	0	0
Ni	34	18	26	52	22	19	48	28	30	32	18	19	27	19	20	28	19	23	17	19
Zr	131	51	72	53	57	86	103	83	301	53	78	114	147	43	47	138	26	70	48	70
Y	17	6	14	32	11	18	44	8	33	14	3	18	14	10	11	36	0	9	1	0
Sr	273	812	1238	442	926	1465	1437	1144	454	712	1362	274	382	691	615	646	629	766	860	1259
Ba	355	41	121	42	46	41	1	42	224	92	61	196	132	56	40	85	65	121	20	63
Rb	71	25	22	24	20	28	41	28	65	19	29	58	38	23	28	29	21	30	22	21
La	21	1	10	1	11	14	13	27	33	18	1	19	27	25	1	33	1	1	1	14
Ce	66	42	47	57	47	83	81	1	73	14	61	39	43	38	80	69	1	21	80	1
Co	18	3	11	14	6	3	5	3	10	12	3	8	17	5	0	7	3	4	2	3

Samples	Cav 1	Cav 2	Cav 3	Cav 5	Cav 6	Cav 7	Cav 8	Cav 9	Cav 10	Cav 11	Cav 12	Cav 20	Cav 21	Cav 23	Cav 24	Cav 25	Cav 26	Cav 27
SiO2	15.85	17.47	27.18	15.12	12	57.19	23.85	18.36	92.72	42.33	65.75	58.67	60.58	60.76	58.38	60.2	38.42	60.5
TiO2	1.12	0.83	0.97	1.14	0.26	0.64	0.39	0.09	0.1	0.2	0.52	0.9	0.74	0.76	0.84	0.76	0.2	0.74
Al2O3	4.03	2.65	4.65	3.79	2.67	14.5	4.88	2.38	2.8	4.87	12.31	16.05	16.72	16.39	16.81	16.88	6.49	15.31
Fe2O3	3.87	4.03	6.64	3.88	3.1	12.64	4.41	5.94	1.08	10.19	3.4	8.06	6.32	6.15	7.51	6.83	2.5	5.73
MnO	0.47	0.59	0.47	0.49	0.52	0.09	0.67	1.01	0.79	0.14	0.14	0.09	0.08	0.09	0.08	0.07	1.13	0.18
MgO	4.28	4.1	5.83	4.22	2.4	6.68	2.44	2.1	0.86	2.96	3.37	5.14	4.39	4.73	5.49	4.71	1.66	4.58
CaO	69.33	69.87	53.8	70.35	78.13	5.18	61.85	69.9	1.23	38.92	10.59	6.04	5.99	5.6	5.06	5.19	47.77	7.52
Na2O	0.4	0.21	0.05	0.38	0.32	1.86	0.62	0.07	0.14	0.12	2.67	2.94	3.76	3.9	3.19	3.8	0.3	3.95
K2O	0.48	0.14	0.3	0.45	0.54	1.1	0.79	0.14	0.25	0.27	1.17	1.96	1.3	1.5	2.5	1.45	1.16	1.34
P2O5	0.17	0.1	0.09	0.17	0.06	0.12	0.1	0	0.03	0	0.09	0.15	0.12	0.13	0.14	0.12	0.36	0.14
L.O.I.	38.27	36.41	33.57	37.43	40.05	7.76	34.42	38.46	3	26.34	10.62	6.95	7.21	6.91	6.25	6.87	29.75	8.35
Cr	112	81	58	118	20	284	67	15	12	32	112	74	65	64	66	59	42	38
V	54	42	57	63	16	84	36	24	12	44	68	139	117	119	134	118	41	106
Nb	23	13	33	22	4	10	3	1	13	2	4	12	12	11	12	12	4	10
Ni	86	56	94	88	24	150	56	26	20	56	75	26	28	27	23	23	27	26
Zr	126	76	198	127	80	167	139	49	16	68	95	144	140	129	134	124	80	133
Y	12	14	19	12	2	25	9	17	1	11	23	23	20	21	18	19	50	27
Sr	612	593	601	604	1035	220	1225	756	53	724	237	378	292	407	507	477	766	583
Ba	37	73	62	129	175	437	551	90	46	89	196	1179	486	637	1088	658	315	595
Rb	31	22	26	31	35	53	45	22	18	27	51	68	58	62	89	60	52	53
La	36	12	51	1	13	19	22	1	5	17	27	20	29	29	38	24	47	35
Ce	91	37	93	92	20	45	34	55	7	40	60	55	54	54	54	54	117	64
Co	16	8	19	18	2	31	8	5	5	19	11	20	19	18	18	18	3	17

TABLE 2 – *Content of* $CaCO_3$ *(wt %) in the castle stones (Rri) and in geological outcrops stones (Cav) determined by calcimetry.*

Samples	Rri 1	Rri 2	Rri 3	Rri 4	Rri 5	Rri 6	Rri 7	Rri 8	Rri 9	Rri 10	Rri 11	Rri 12	Rri 13	Rri 14	Rri 15	Rri 16	Rri 17	Rri 18	Rri 19	Rri 20
CaCO3	13.9	85.4	74.2	70.3	75.4	78.4	79.4	83.4	33.2	51.9	72.5	28.8	49.5	78.4	80.4	82.3	85.1	87.2	76.4	87.2
Samples	Cav 1	Cav 2	Cav 3	Cav 5	Cav 6	Cav 7	Cav 8	Cav 9	Cav 10	Cav 11	Cav 12	Cav 20	Cav 21	Cav 23	Cav 24	Cav 25	Cav 26	Cav 27		
CaCO3	68.6	74.4	78.4	85.0	82.4	8.9	80.4	83.3	1.0	62.7	20.6	3.0	6.9	6.9	6.0	4.9	68.3	10.9		

complete characterisation of the stones sampled in the castle and near the outcrops. Such stones are described in the following sections.

STONES OF THE CASTLE

Most of the stones in the castle walls show a rather different macroscopic aspect (Fig. 3); however, dark grey coloured blocks which confer to the structure a homogeneous aspect on the whole, prevail.

The castle rocks can be subdivided into eight distinct types (Correns, 1968; Folk, 1968): marly limestone (Rri 2, Rri 17, Rri 20), calcareous marl (Rri 3, Rri 4, Rri 5, Rri 11, Rri 14, Rri 15, Rri 16, Rri 19), marl (Rri 10), coarse-grained biocalcarenite (Rri 8, Rri 18), fine-grained biocalcarenite (Rri 6), very fine-grained biocalcarenite (Rri 7), arkose (Rri 9, Rri 12, Rri 13), quartz arenite (Rri 1).

Marly limestones have high cohesion, and macroscopically show a homogeneous brown-grey colour (Fig. 3). They show a homogeneous aspect and are represented by micritic calcite (Fig. 4), and sometimes microsparite. The pores have irregular shape, ranging in size between 0.03 mm and 0.1 mm.

Calcareous marls are the most spread rock types in the castle walls. Their macroscopic aspect is very variable (Fig. 3), especially in colour. In fact, white-pink, grey-dark or even brown-reddish calcareous marls can be observed. In thin section, crystals are not resolvable; rare round pores (0.2<Ø<0.6 mm) filled with microcrystalline calcite can be observed. The texture on the whole is micritic, rarely cryptocrystalline and lacking in pores.

The *marls*, prevalently light-grey in colour (Fig. 3), show a typical conchoidal fracture and are often crossed by fractures filled with visible calcite crystals either macroscopically or in thin section (Fig. 4). Most of the marls have a very fine grain size which is not resolvable on the microscope, but in some samples very small quartz crystals, dispersed in a micritic matrix, can be recognised.

Biocalcarenites are scarcely used in the castle walls; in fact, they are mainly adopted to embellish the rooms' entry doors and the towers. These rocks range in colour from white-pink to light-brown. Coarse-grained biocalcarenite are characterised by a low cohesion; the fossils of the framework are visible to the naked eye and have an average size of 2 mm (Fig. 3). In thin section there are several fossil fragments, while quartz, orthoclase, plagioclase and biotite are more rare. The sparitic matrix is nearly totally interested by dissolution due to diagenesis. Dissolution pores range in size from 0.3 to 0.4 mm (Fig. 4). Fine-grained biocalcarenite shows a straw–yellow macroscopic colour (Fig. 3). Cohesion is rather low; in fact, it is possible to break the sample by hands. In thin section (Fig. 4) its framework appears to be totally built up of bioclasts with dimensions varying from about 0.2 to 1 mm: the sparitic matrix evidences dissolution processes with clear irregular shaped pores (0.1< Ø <0.6 mm).

The very fine-grained biocalcarenite has a white-pink macroscopic colour (Fig. 3) and shows an average cohesion; sometimes the sample appears dusty to touch, which is a sign of possible active deterioration processes; thin section analysis evidenced a framework made up of micro-foraminifer skeletons (Fig. 4) with an average size of 0.3 mm. In the sparitic matrix, rare subcircular-shaped dissolution pores are visible.

The *arkose* sampled within the castle show a greyish macroscopic colour (Fig. 3). In thin section they appear prevalently made up of microcrystalline quartz fragments, muscovite, plagioclase, biotite, chlorite and rare opaque minerals; the framework

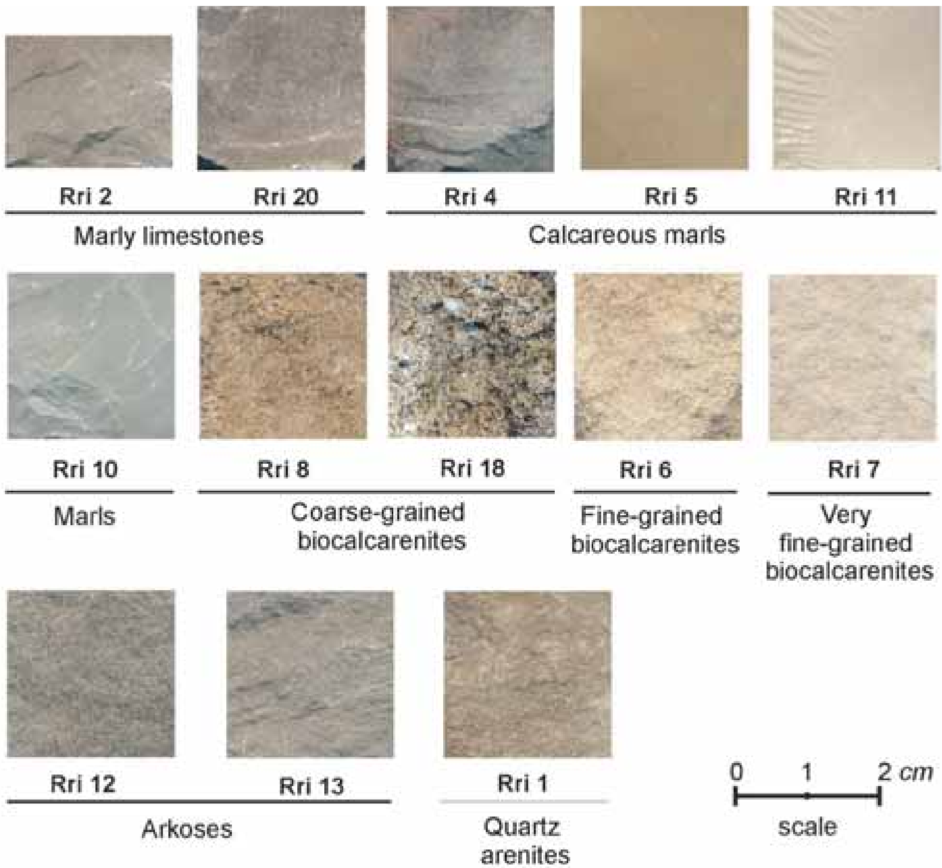

Fig. 3 – Macroscopic representative stones of the castle.

grains are cemented by micrite covering a surface included between about 12 and 30% of the whole section. The clasts average size are 0.12 mm. Porosity is low.

The *quartz arenite* is the less diffuse rock type in the castle. It appears macroscopically homogeneous and shows a dark-brown colour (Fig. 3); in thin section, this rock type exhibits a framework prevalently made of sub-angular quartz monocrystalline grains. Biotite, muscovite and rare orthoclase and plagioclase crystals are observed. The micas in some sandstone samples appear partially isoriented. The clasts have an average size of 0.23 mm. The pores are scarce; they are prevalently irregularly shaped and their size is between 0.03 and 0.5 mm.

Stones of the local outcrops

The sampled outcrops around Rocca Imperiale are indicated in Fig. 2. The identified rock types can be divided into calcareous marls (Cav 1, Cav 2, Cav 3, Cav 5, Cav 6, Cav 9, Cav 26), marls (Cav 11) and quartz arenites (Cav 7, Cav 21), which have the same petrographic and macroscopic peculiarities described in the previous section. In such outcrops there are also calcarenites (Cav 8), quartz-feldspatic sandstones (Cav 20, Cav 23, Cav 24, Cav 25, Cav 27), lithic graywackes (Cav 12) e cherts (Cav 10), unused in the castle construction but potentially utilizable as building material. In fig. 5 some representative samples of the studied rocks are shown.

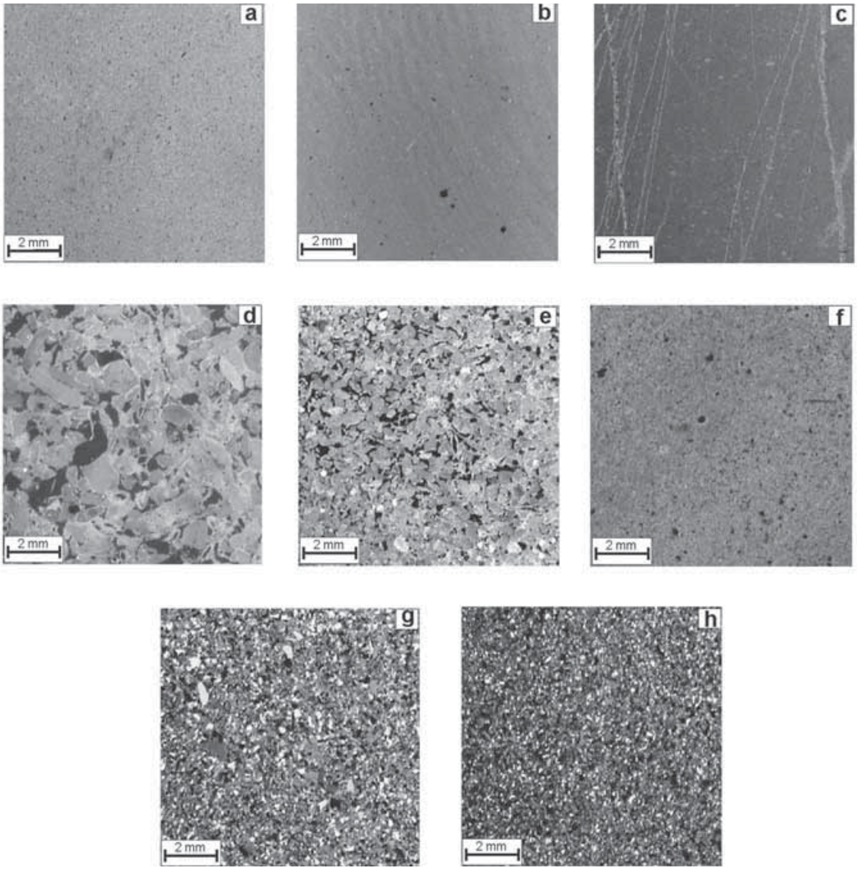

Fig. 4 – Photos acquired through flatbed scanner in transmitted polarized light; representative stones of the castle: a) Rri 2, marly limestone; b) Rri 19, calcareous marl; c) Rri 10, marl; d) Rri 8, coarse-grained biocalcarenite; e) Rri 6, fine-grained biocalcarenite; f) Rri 7, very fine-grained biocalcarenite; g) Rri12, arkose; h) Rri 1, quartz arenite.

The *calcarenites* macroscopically show a homogeneous brown-greyish colour and have a very high cohesion. In thin section they have a framework made up of micro-foraminifer fragments, quartz and altered plagioclase (Fig. 5c); average sizes are 0.2 mm. The matrix is mainly represented by micrite. The pores are prevalently irregularly shaped (0.03< Ø <0.6 mm).

The *quartz-feldspatic sandstones* macroscopically show a dark-brown colour. They appear homogeneous and of elevated cohesion. In thin section, a framework made of diverse plutonic and metamorphic rock fragments is observed (Fig. 5e). The framework grains range in size from 0.1 to 2 mm and are sub-angular. The matrix takes up less than 15% of the whole thin section. The identified framework minerals are quartz, orthoclase, plagioclase, muscovite, biotite and chlorite; carbonate fragments are rare. Porosity is very low.

The *lithic graywackes* macroscopically show a homogeneous brown-greyish colour and have high cohesion. In thin section the grains forming the framework have an average size of 1 mm (Fig. 5f) and are angular. There are many quartz fragments and the matrix takes up about 15-20% of the thin section. Identified minerals are quartz,

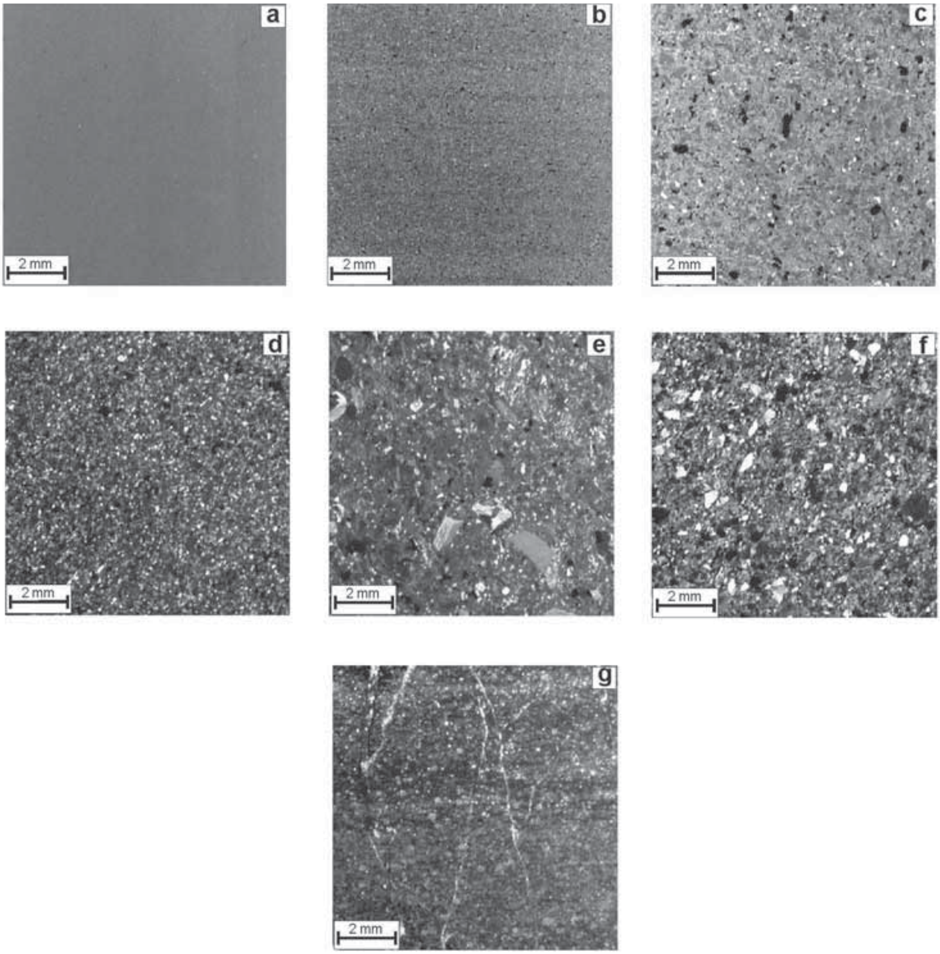

Fig. 5 – Photos acquired through flatbed scanner in transmitted polarized light; representative stones of the local outcrops: a) Cav 3, calcareous marl; b) Cav 11, marl; c) Cav 8, calcarenite; d) Cav 21, quartz arenite; e) Cav 20, quartz-feldspatic sandstone; f) Cav 12, lithic graywacke; g) Cav 10, chert.

plagioclase, biotite, muscovite and chlorite. Pores are prevalently irregular shaped (0.03< Ø <1 mm).

The cherts, macroscopically show a brown-reddish colour and have a typical conchoidal fracture. In thin section (Fig. 5g) rounded structures (radiolarites), plunged within an extremely homogeneous reddish matrix, are observed. Fractures which are partially filled with quartz, and rarely with calcite, are visible.

Provenance of the stones

Marls, calcareous marls, and quartz arenites, forming most of the stones by which the castle was made, have probably a local provenance. Such stones exhibit a remarkable geochemical similarity, showing the same petrographical characteristics as the ones sampled nearby the local outcrops. Moreover, it is clearly visible how the diverse compositional fields perfectly overlap one another (Fig. 6).

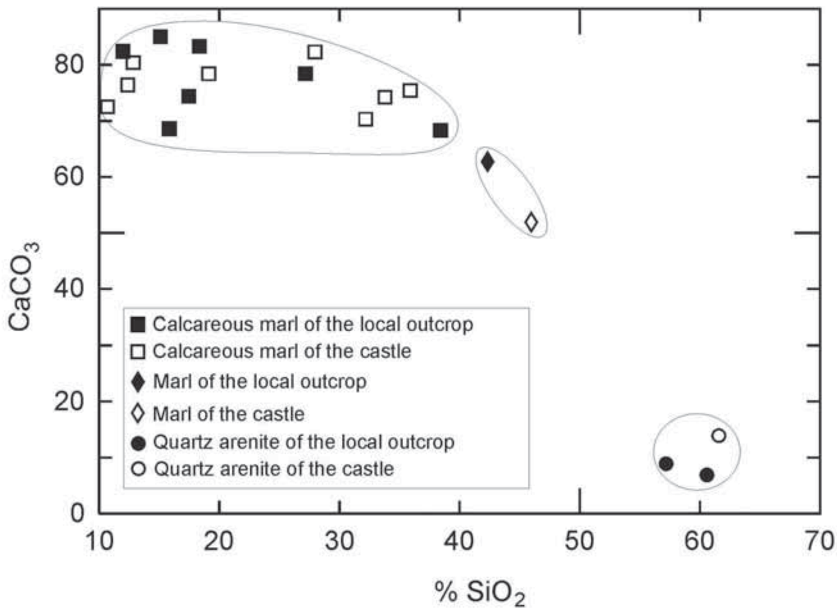

Fig. 6 – Geochemical comparison among calcareous marls, marls and quartz arenites of the castle with calcareous marls, marls and quartz arenites of the local outcrops.

Marly limestone and sandstones were also sampled on the castle. Even though such stones were not recognised in the nearby local outcrops during the sampling, they have been reported in the area by Ghezzi (1973), within the shale and siliciclastic calcareous-arenaceous unit; thus, a possible local provenance for them is plausible.

Different considerations can be done for biocalcarenites; indeed, comparing the major element chemical composition of the castle biocalcarenites with that one of calcarenites with microfossils sampled nearby Rocca Imperiale (Fig. 7a), it appears evident how the castle samples (Rri 6, Rri 7, Rri 8 e Rri 18) are, on the whole, homogeneous, while the sample Cav 8 shows a content in CaO which is relatively lower than the others. Furthermore, in Fig. 7b an anomaly for the barium separates very well the sample Cav 8 from the others. In fig. 7b it is visible that the pattern Rri 18 shows a rather low strontium content, which is not to be related to an original non-homogeneity with respect to samples Rri 6, Rri 7 and Rri 8. Conversely, it is rather due to the intense sample deterioration, connected to the presence of the carbonatic binder dissolution processes, clearly observed in thin section (Fig. 8). We may thus affirm that the castle biocalcarenites do not have a local provenance; in fact, this rock type does not outcrop in the Rocca Imperiale area. Taking into account the geographical proximity with the Puglia region and the remarkable compositional similarities with the calcarenites in this region (D'Alessandro & Iannone, 1983; D'Alessandro *et al.*, 1979, 2004; Rodolico, 1995; Andriani & Walsh, 2002), a provenance of this rock type from the Puglia region can be regarded as reasonable.

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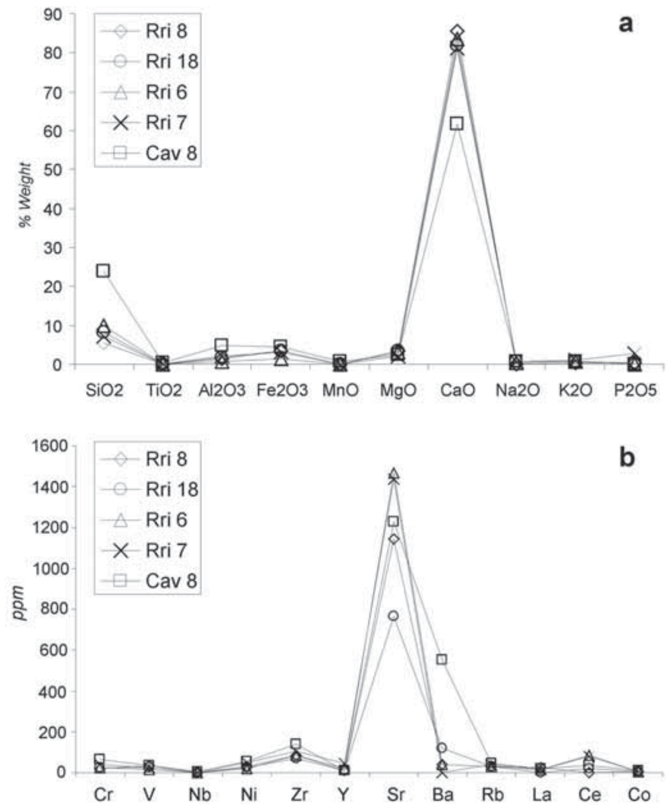

Fig. 7 – Geochemical comparison between the biocalcarenites of the castle (Rri) and the calcarenites of the local outcrop (Cav). a) Trend of the major elements; b) Trend of trace elements.

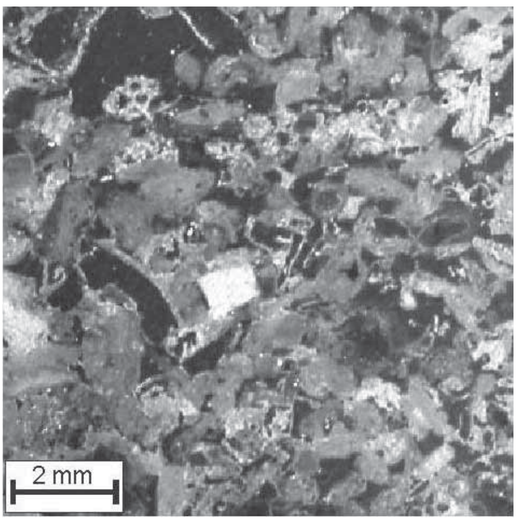

Fig. 8 – Microphotography of the coarse-grained biocalcarenite (sample Rri 18).

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