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Alteration processes of geomaterials used on the pentagonal tower of Serravalle Castle (central-west Sardinia, Italy)

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Abstract

The pentagonal tower belong to medieval Serravalle castle area (81 m. above sea level), near the mouth of the Temo River. The castle is important medieval fortifications of Sardinia and was built in various stages. The oldest part was constructed by Marchesi Malaspina of Villafranca which arrived in Sardinia at the 12th century (1112-1121). The earliest fortification was the four corner towers about 10 m tall, linked by a thick wall. The pentagonal tower, located in the western corner of the boundary dates about 1330, probably was consisted of two storeys with wooden beams, now missing, and one stone one with a longitudinal arch. In the structure was used local volcanic rocks (i.e., pyroclastites) belonging to the Oligo-Miocenic volcanic cycle of Sardinia (32-11 Ma). According to De La Roche classification (1980), the pyroclastic rocks have a composition varying from dacite to rhyolite and show a porphyritic structure (I.P. from 10 to 20%) for phenocrystals of opaque (ilmenite, magnetite and/or titanomagnetite), plagioclase, ± biotite, and rare hornblend and quartz. Two main type of volcanics are present with different physical properties (porosity, density, etc.) and petro-volcanological characteristics (e.g., welding degree): cineritic pyroclastites, little welded, with average values of open porosity and bulk density of 36.3±2.6% and 1.50±0.07 g/cm3, respectively; lava-like ignimbrites, from medium to high welded, and average values of open porosity and bulk density of 22.5±5.9% and 1.99±0.15 g/cm3, respectively. As function of these different features and extremely heterogeneous, due to variable incidence of pumice, lithic- and crystal-clasts, the alteration is present mainly on volcanics with low welding and exposed to the sea-winds. Due to marine aerosol, salt efflorescences are present. These latter, together thermal and hydric cyclic dilatation, lead to various macroscopic physical alterations (decohesion, chromatic alteration, pitting, exfoliation, flaking, alveolation, differential degradation between the lithic-clasts and the vitreous matrix).

Keywords: tower fortification, decay, alteration, pyroclastites.

1. Introduction

The medieval castle of Serravalle (Fig.1), located at the top of the hill of the same name (81 m. above sea level), near the mouth of the Temo River, is one of the best-known medieval fortifications in Sardinia. The construction of the oldest part of the castle (according to Giovanni F.Fara, bishop of Bosa in the late sixteenth century), is attributed to the Marchesi Malaspina di Villafranca, on their arrival in Sardinia, and is dated to the beginning of the 12th century (1112-1121; Angius, 1831). Recent studies, however, tend to shift both the arrival of the Malaspina and the birth of the castle to the following century. They founded the new town of Bosa, moving the original nucleus called Bosa vetus two kilometres downhill; thus the late medieval village of Sa Costa (which makes up the historical centre of present-day Bosa) began to develop; it still exerts considerable historical fascination.

Fig. 1- Actually photo of plan of Serravalle Castle (Bosa, central-west Sardinia, Italy)

According to studies undertaken by Raymond Paper Raspi and Foiso Fois, from an architectural point of view, the complex was built in stages, starting in the second decade of the twelfth century. The construction of the first fortification followed the implementation of the four towers cantonal high about 10 m, connected by a thick wall, with a similar pattern to that of the castle of S. Michele in Cagliari. Of these towers remained almost intact only one: that of the west edge (Spanu, 1831). One of the most important moments can be identified in the construction, attributed to Giovanni Capula, the "Mastio" Tower (Fig. 2) of the Serravalle castle to replace north cantonal tower, in the early fourteenth century, it is likely that ' additional fortification was built by the Pisani in order to counter the Aragonese invasion of the island, as is suggested by comparisons with similar buildings in Cagliari (tower of 'Elephant' and San Pancrazio tower), it probably housed the garrison commander of defense of the castle and his most trusted men.

This tower is the real mastio of the fortification, is built in part with pyroclastic rocks of ocher and light, in part, with blocks of ignimbrite purplish, used for the construction of ashlar at the base of the tower.

Three wooden antlers and two masonry-vaults allowed operations from the slits.

Fig. 2- "Mastio" tower of Serravalle Castle.

Outside, on the north side, they were placed in an unknown time, two ashlars with heraldic coats of arms (one of which probably with the weapons of the Spanish feudal lord Giovanni di Villamarí), restored with the tower at the end of the last century. Later, to defend the castle, the walls were raised (are still readable in the walls of the north side of the battlements occluded following the elevation) and was also expanded with the creation of a second wall structure forming a trapezoid.

Angles west and south of the new boundary-wall took on the form of pentagonal towers of the same height of the wall. In this way the complex reached the perimeter 300 m, enclosing an area of over one hectare. Can be traced back to this period, around 1330, the elevation of the pentagonal tower, object of study of this work, situated in the west of the boundary-wall.

2. The pentagonal tower

The tower was built in pyroclastite grey with four horizontal bands of purple ignimbrite (Figs. 3, 4); it probably consisted of two levels, one of which is a wooden beams, now absent, and a stone-vaulted arched. On the first floor two doors architraved allowed passage of soldiers to patrol steps arranged along the wall that connects all the towers (Spanu, 1981). On the second floor there are two louvers: one facing south overlooking the river Temo, the other facing north with views of the estuary and the port.

Fig. 3- View from NW of pentagonal tower.

Other major changes (such as the construction of three stands with embankment to the location of firearms) were decided by the feudal lords Pietro Ledesma in 1433 and Giovanni di Villamarí, admiral of the Aragonese fleet, since 1468. Within the walls, the parade ground of the castle, perhaps incorporated early age Aragonese, was built in the fourteenth century church of San Giovanni, and St. Andrea (today's NS Regnos Altos), recently restored. In a tempera French seventeenth century, the fort now seems complete, and the city is welded to the castle by an imposing city walls (are relevant traces that can be seen on the eastern side), descending from the top of the hill along the two staircases extreme, guarding the village to the river. The beginning of the decline of the castle is documented in 1571. In the Spanish Parliament in 1575, the representatives of citizens urged an action to restore the fortifications. In the last century, the city walls were torn down and began, according to the indications of new urban instruments (the so-called "Plan ornate"), the building development towards the sea. The castle was then variously reworked, with the restoration Filippo Vivanet and Dionigi Scano (1893), which mainly concerned the master tower. In our century, the castle has undergone numerous restorations made, in most cases, by the Department of National Heritage Monumental of Sassari. Recently (since 1999) were performed restorations of some parts of the walls.

Fig. 4- View from SE of pentagonal tower.

3. Sampling and analytical methods

From the pentagonal tower were collected about twenty samples of welded and light welded pyroclastites with different characteristics.

The rock fragments were sampled according to different heights in the facade of tower and with different decay degree. This method allows to highlight the probable change of materials related to various construction phases. Then each sample were worked in laboratory and are made: pseudo-prismatic specimens on which to determine the physical properties (density, porosity, water absorption, saturation index, etc.); thin sections with a thickness around 30 μm for petrographic determinations of mineralogical composition by optical polarised microscopy.

4. Results

4.1 The pyroclastic rocks

The tower, which probably consisted of two storeys with wooden beams, now missing, and one stone one with a longitudinal arch, was built using pyroclastic rocks belonging to the Oligo-Miocenic volcanic cycle (Beccaluva et al., 1989; Columbu et al., 2011; Coulon, 1977; Cherchi & Montadert, 1982; Dostal et al., 1982; Lecca et al., 1997) occurring in Sardinia between 32 and 11 million years ago (Beccaluva et al., 1985; Savelli et al., 1979). These volcanic rocks are used in different historic periods in Sardinia for construction of monuments from Roman to medieval (Melis & Columbu, 1998; Columbu et al., 2014b, 2015) or for ancient tools (i.e., Roman millstones made in Sardinia and exported in north-Africa; Antonelli et al., 2014).

The analyses macroscopic and microscopic showed the presence of four rock types with different petro-volcanologic characteristics:

- strongly welded pyroclastites, with deep purple colour, (called FS), type lava-like ignimbrite;

- welded pyroclastites, light purple or pink, (S), type ignimbrite;

- medium-low welded pyroclastites, gray-green, (P1, P2), type pumice-cinerite;

- lightly welded pyroclastites, grey-green, (P3), with the same matrix of the preceding P1 and P2, but with a higher percentage of lithic and pumice, type pumice-cinerite.

4.2 The alteration processes and its macroscopic forms

The volcanic rocks of the pentagonal tower, as demonstrated by some studies (Columbu et al., 2013, 2014b; Coroneo & Columbu, 2010; Macciotta et al., 2001), show mainly a physical decay. Considering the high porosity (30-45%), in majority of cases this decay is concentrated in the basal parts of structures, due to the presence of circulating solutions, often characterized by the presence of salts. For these reasons, especially if close to the sea, this process continues the process of absorption / desorption of salt solutions, associated with crystallization of salts, it causes evident alterations in the material surface.

Moreover, as evidenced by some scientific works (Columbu et al., 2014a; Lopez-Doncel et al., 2012; Weiss et al., 2004), the same absorption of water causes a dilation hygroscopic and water of volcanic rocks with consequent pressure between the ashlars of masonry-wall. All these degradation processes are manifested then with various macroscopic forms of alteration.

The most common ones in the tower are:

- alveolation, with formation of alveoli with geometry (shape, size, depth, etc.) variable;

- exfoliation, usually sub-parallel to the surfaces of the facades, but also with orientations according to preferential directions of anisotropy of volcanics (e.g., flow or stratification planes of these volcanic deposits);

- differential alteration, where components are present more resistant to alteration (e.g., lithic, mineralogical clasts) immersed in a glassy matrix less resistant;

- decohesion and disaggregation, especially among micro-fragments of glassy matrix or internally in the case of volcanic pumice with low welding. In smaller percentage are found pitting, evident chromatic alteration and biological patinas.

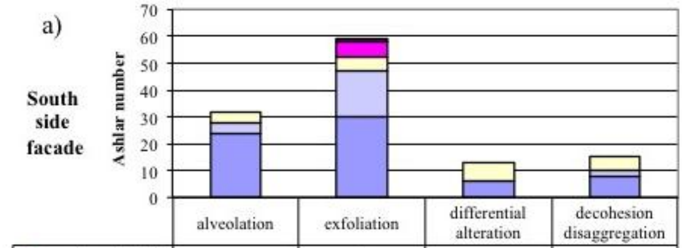
The distribution of these alteration forms is not random, but is linked to both the petrophysical characteristics of the rock and the exposure, to the main agent of weathering: the wind (especially to the north) and the marine aerosol.

Also the degree of physical alteration depends largely on the petrographic-physical characteristics of pyroclastites:

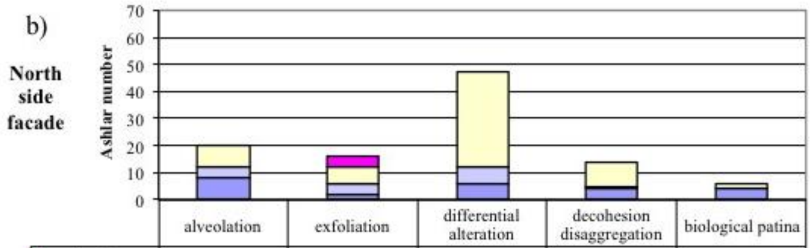
- welded (S) and strongly welded (FS), characterized by lower porosity values show understandably a slightly physical alteration and some forms (i.e., alveolation) are never found;

- slightly to normally welded (P1, P2, P3) show a greater alteration degree, in some cases with the disintegration of ashlars.

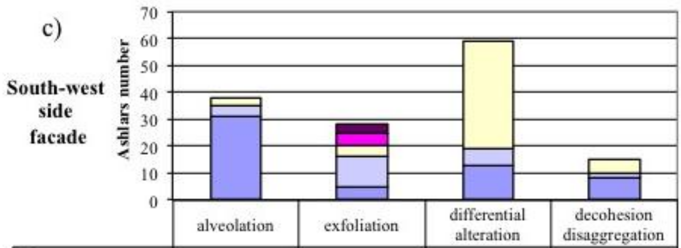
For to evidence better the decay distribution, for each side of the tower it is made a series of histograms (Figs. 5 a, b, c, d, e) showing on the abscissa the decay forms most typical and in ordinate the number of the ashlars affected by decay; also for any alterations they have distinguished the rock types affected.



	alveolation	exfoliation	differential alteration	decohesion disaggregation
strongly welded FS		1		
welded S		6		
low welded P3	4	5	7	5
low welded P2	4	17	0	2
low welded P1	24	30	6	8

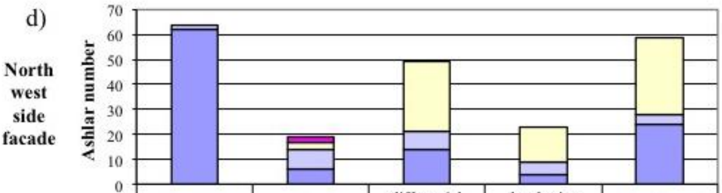


	alveolation	exfoliation	differential alteration	decohesion disaggregation	biological patina
welded S		4			
low welded P3	8	6	35	9	2
low welded P2	4	4	6	1	0
low welded P1	8	2	6	4	4

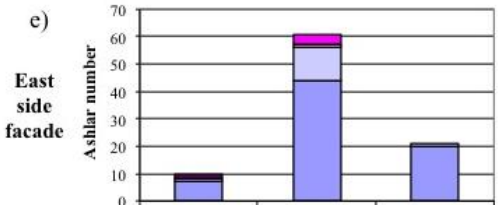


	alveolation	exfoliation	differential alteration	decohesion disaggregation
strongly welded FS		3		
welded S		5		
low welded P3	3	4	40	5
low welded P2	4	11	6	2
low welded P1	31	5	13	8

Figs. 5 a, b, c- Distribution of macroscopic physical alteration forms on the south side (a), north side (b) and south-west side (c) of pentagonal tower of Serravalle castle (Bosa).



	alveolation	exfoliation	differential alteration	decohesion disaggregation	biological patina
welded S		2			
low welded P3		3	28	14	31
low welded P2	2	8	7	5	4
low welded P1	62	6	14	4	24



	alveolation	exfoliation	crust
strongly welded FS	2		
welded S		4	
low welded P3	0	1	
low welded P2	1	12	1
low welded P1	7	44	20

Fig. 5 d, e- Distribution of macroscopic physical alteration forms on the north-west side (d) and east side (e) of pentagonal tower of Serravalle castle (Bosa).

5. Discussion and conclusions

The decay is mainly physical type, apparently they not now found chemical alterations, probably because the physical process is faster than the chemical transformation for which is not seen.

The results of macroscopic analysis of tower facades show that in the welded and strongly welded pyroclastites (lava-like ignimbrite) the alveolation is absent and the exfoliations and differential alteration are rare, however always superficial, sometimes with the possible presence of fouling (i.e., crust).

Only in some ashlars on the east side of tower they were found pitting.

The alteration forms are more concentrated on the rock types P1, P2 and P3 with a few differences between them. The alveolation is present in most rock types P1 or P2, with less than is found on P3 rock types.

For rock types P1 often there are alveoli larger than the cm (Fig. 6), with a tendency to elongation and an iso-orientation.

Fig. 6- Alveolation with different size of alveoli (15-80 mm) with lightly iso-orientation, related to different welding inside the same ashlars.

The rock types low welded P3 are most affected by alteration differential, with enucleation processes of lithic and minerals more resistant, and with forms of decohesion, flaking, or disintegration of the ashlars.

Observing the distribution of the decay macroscopic forms in the facade of tower one notes that: i) in the sides to south and east (with greater) are present mainly exfoliation and chromatic alterations due to thermal/hygrometric dilatations and sun radiation, respectively; ii) in the sides to west and north-west are present mainly alveolation and differential alteration, due to exposure to the sea-wind and marine-aerosol. In the facade exposed to north is present also biological patina, due to absent of sun radiation.

Then, a difference is read by observing the distribution of the forms of decay from top to bottom, in the highest part and in that the medium-low there is a greater alteration, also evidenced by the presence of numerous recent ashlars that in the previous restoration have replaced ashlars totally altered.

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