Destroyed Places and Ancient Wars. Digital Tools for the Montecastrese Fortress

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In the XXth century, a series of archaeological excavations brought to light the settlement named "Montecastrese," a system of Medieval fortifications located on the top of a hill near the town of Camaiore, on the Tyrrhenian coast of Italy. The site had been abandoned for centuries before the archaeologists brought to light traces of the fortress and of the village, exploring the monumental ruins of the northern tower, still in place but consisting of ruins in two main areas. In the first half of the XIIIth century, the castle of Montecastrese was conquered and destroyed by the army of Lucca. At the time of its major development, the small fortress was organized around two main towers, with walls and houses. A quite extensive village was located on the southern side of the hill. In 2015, the municipality of Camaiore commissioned the Dipartimento di Architettura in Florence to make a complete digital survey of the area. The general survey plan was made using an aerial photogrammetric survey, a 3D laser scanner survey and terrestrial photogrammetry. The 3D modeling of all the lost parts, from the houses, to the defense walls, to the system of towers, was one of the focal points in this work, which used the modeling process from the survey and supported the reconstruction hypothesis with previous archaeological data. At the same time we matched the missing parts with similar architecture and took into account the defensive and offensive features of the medieval fortress. For the northern tower, a specific operation based on the use of 3D printed models was employed in order to settle the debate about the sequence of the tower's collapse. This was quite important to the digital reconstruction of the building, and the direct manipulation of a scaled model turned out to be a fundamental step for the completion of this part of the research.

Key words:
Montecastrese; 3D reconstruction; Medieval archaeology; Digital survey; 3D printing.

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1. INTRODUCTION

The purpose of our study was to make a reconstructive hypothesis about how the fortified village of Montecastrese, in the Versilia region of Tuscany (Italy), appeared in the past. To do this, it was necessary to analyze the written sources and the archaeological remains, to make a comparison with other castles of this area, and to perform a survey of the area of interest, resulting in the production of three-dimensional virtual and printed models of the elements involved.

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2. THE STORY SO FAR

Montecastrese was quite probably the most important and populated castle in Versilia. In the Middle Ages, Versilia counted a large number of castles, many of which have disappeared, and of those remaining we can see only scanty ruins covered by vegetation or located on steep slopes.

As shown in Fig 1, in the area of Camaiore it is possible to recognize the remains of fifteen fortified sites, which can be divided into three main typological categories [Gattiglia and Anichini 2009]:

- Fortified villages, with or without *cassero* (from the Latin word *castrum,* indicating a fortified military camp, used in castles to indicate their upper portion with fortified buildings)
- Manor houses with surrounding land and buildings
- Military fortifications, built at strategic points and settled by soldiers

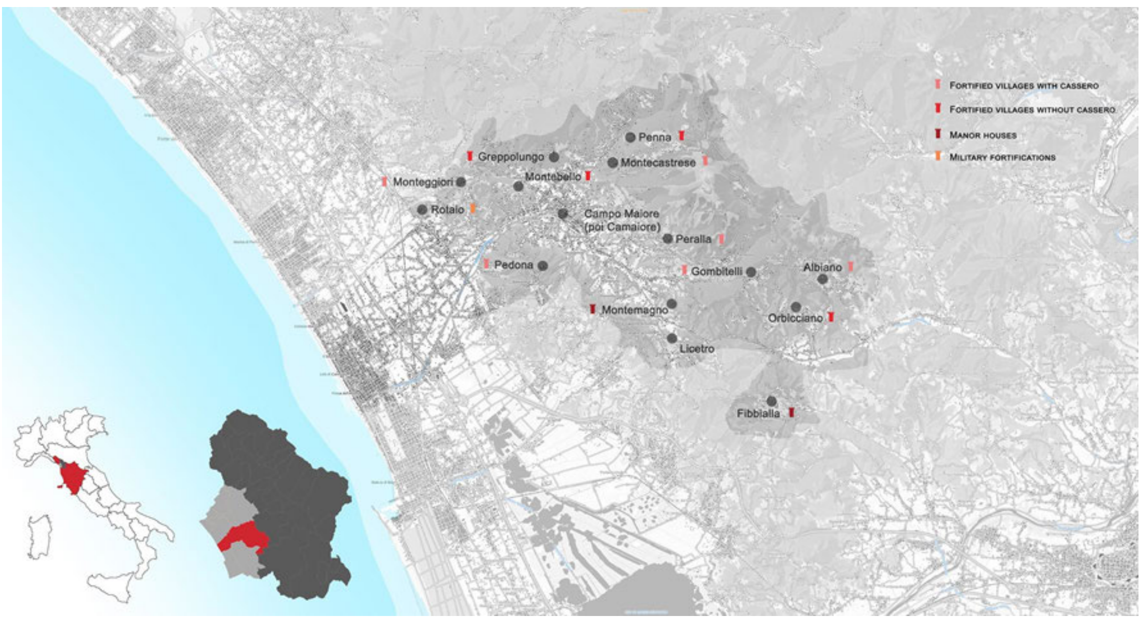

Figure 1. The location of the Montecastrese settlement, highlighting the main fortifications in the area.

Montecastrese belongs to the category of fortified villages with a *cassero* [Panero and Pinto 2009]. The importance of the *castrum* of Montecastrese is demonstrated by the significant amount of archaeological remains found on the top of Monte La Torre (290 meters above sea level), close to the town of Camaiore .

The *castrum* was located in a strategic position, between two rivers, with a good view over the valley of Camaiore, including some roads and a passage that led to the silver and iron mines. The archaeological investigations helped us to understand the development of Montecastrese. From the first settlement, in perishable material, dating from the VIIIth to Xth centuries AD, the castle was gradually completed around the twelfth century. The castle was surrounded by a double wall: the first contained the *cassero*, which was the highest part of the castle, and was probably inhabited by the soldiers; the lower boundary enclosed a village of a hundred houses. These buildings were placed for the most part on the southwest side of the hill, because of the conformation of the ground and in order to receive more sunlight.

If we consider the number of the houses and the area covered by the village (about 15,000 square meters), we can estimate that around five hundred inhabitants lived here, so Montecastrese was the most populous and largest castle in Versilia. Two square towers stood in the *cassero*. They were placed in the northeast and southwest ends of the crest of the hill.

The North Tower (Fig. 2) was probably the keep (*mastio*), that is to say the main tower and last refuge; it was surrounded by a defensive wall closed on the east side by a guardhouse. The south tower, in contrast, was linked to an earlier rectangular building that was believed by the archaeologists to be a *dongione* (a residential tower) dominating the valley of Camaiore [Antonelli 1995].

Figure 2. The remains of the northern tower; lower part, view of the southern front.

The analysis and reconstruction of the main tower are the focal point of this research. At present, there are significant remains in place: the base that was cut off and the main collapsed body. This part is still lying on the ground, but has been split in two parts since the 1970s, perhaps after an earthquake. In this area is it possible to see some large fragments, while others have probably fallen downstream. Historically, the tower fell because of the destruction of the castle after the conquest of the fortress by the army of Lucca in 1224. Between the twelfth and thirteenth century, Versilia was involved in a long war between Lucca and Pisa for the control of the coast. The local lords had to face the expansion of the two cities, making alliances with them [Stortoni 1993].

Many of the castles were gradually taken and destroyed, until Lucca completed the occupation of Versilia in 1254. After a victory, the tradition of the army of Lucca was usually to destroy all the buildings belonging to the defeated enemy. So, after the conquest of the castle of Montecastrese, the main tower was torn down (as shown by traces of mine operations), collapsing in the north-eastern part of the site [Santini 2002]. The inhabitants of Montecastrese were then forced to move into the new town of Camaiore, founded by Lucca. Thus, the site was gradually abandoned until, at the end of the fifteenth century, the area was planted with olive trees. This allowed the partial preservation of the archaeological remains [Gattiglia and Tarantino 2013]. During the twentieth century, a series of excavations brought to light all the major remains from this settlement, and in 2015 the municipality of Camaiore required a complete digital survey of the area to better document the site and contribute to the local museum dedicated to the town's history.

3. THE NEW SURVEY CAMPAIGN

This complex of ruins was documented using an indirect digital survey, performed with tools capable of collecting a huge number of measurements in a very short time. In this digital survey work the timeline was not on the side of the surveyors: the commitment of the research was signed at the end of February, and the work was to be done before the beginning of spring. This area has many tall trees, especially around the northern tower and all along the western side of the hill. Due to this situation, it was important to complete the survey before the foliage came out. Because of the large extent of the area, its long development and the irregular shape of the ruins, the integration of four different kinds of survey was necessary in order to ensure an effective control of the measurements and shorten the overall time needed for the survey campaign:

- 3D Laser scanner survey
- Topographical survey (in support of the 3D LS and photogrammetric survey)
- Aerial photogrammetry
- Terrestrial photogrammetry

The main survey campaign took place in three days. An inspection was made to choose the topographic route and the best locations for 3D laser scanner stations. A sufficient number of targets was placed all along the area. The stations were chosen by determining the number of targets that each station was able to reach. As a criterion, we decided to have each two consecutive stations obtaining at least the same four targets. To facilitate the connection of this network with aerial photogrammetry, a certain number of targets were placed directly on the ground and blocked with nails. The terrestrial photogrammetric survey was conducted in two separate days, chosen for specific weather conditions, with a fully cloudy sky, to allow smooth shadows and homogeneous lighting. A video showing all the main survey activities can be viewed at: https://youtu.be/tJxZACQc4yY

3.1 3D Laser Scanner

The 3D Laser scanner survey was operated using a phase shift laser unit, a Zoller+Fröhlich (Z+F) 5006h model. This very efficient tool allowed us to acquire the area of interest as a digital three-dimensional model, consisting of a system of point clouds resulting from the connection on the topographical network of several scans. The scanning stations (Fig. 3) were concentrated around the main built elements, first of all the NorthTtower. The operations carried out with the 3D laser scanner led to a total of 196 scans from 192 stations, with the acquisition of around 1 billion points.

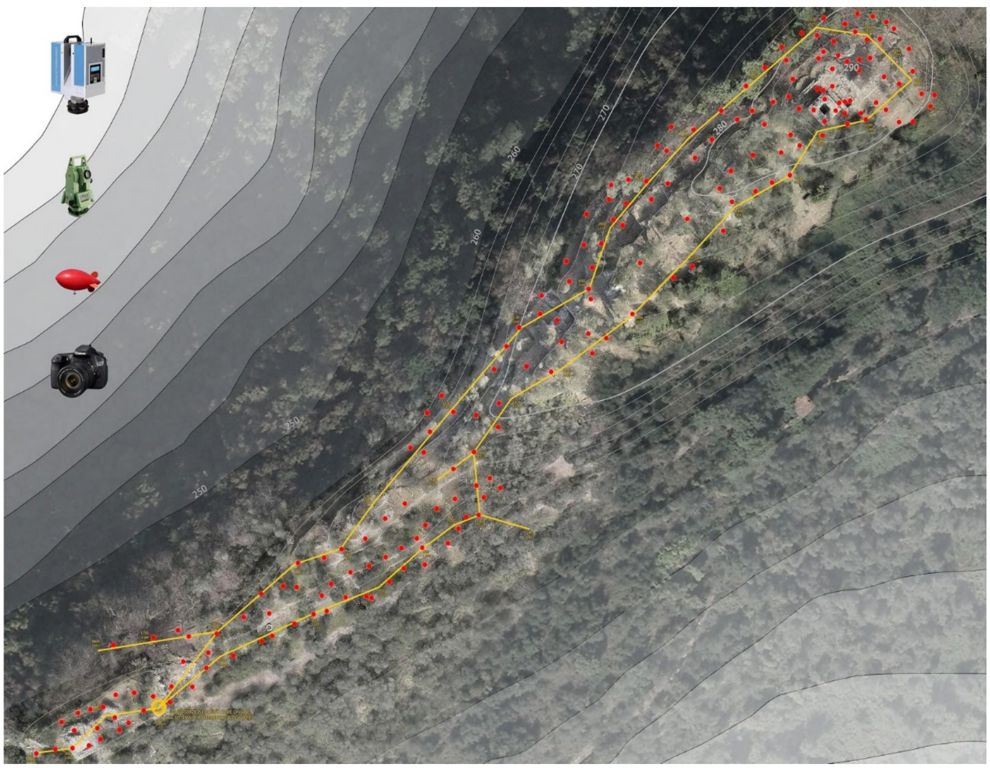

Figure 3. The complete network of the digital survey on the Montecastrese hill.

3.2 Topographical Survey

In order to simplify the system of measurements and to correctly connect all the scans, avoiding the need for large overlapping areas, a topographic survey with a total station was clearly the best choice. From 38 station points the targets acquired by the 3D laser scanner were measured and structured as a reference network for each point cloud. The narrow development of the hill, the numerous trees and the terraces were not a significant obstacle for this kind of measurement. This part of the survey gave a solid base to the overall workflow, reducing to the minimum the possibility of alignment errors and progressive misalignments.

3.3 Aerial Photogrammetry

The previous phases of the survey gave us the shape and the dimension of the site, but not the chromatic description of the materials. To complete the documentation and to expand the coverage of the survey area, we decided to undertake an aerial photogrammetry of the whole settlement. Because of the quite robust winds coming up from the both sides of the hill, it was preferable to use a six-meter-long aerostat filled with helium gas and equipped with a radio-controlled gimbal and camera (Fig. 4). This mini-balloon was able to overcome the difficult conditions caused by the winds (even though there were still some difficult moments).

Figure 4. The mini-balloon at work over the ruins of the Montecastrese hill.

The selected set of 750 pictures, taken with a Canon 60D and a Canon G10, were used to create a general model by Structure from Motion (SfM) using the software, Agisoft Photoscan. The final mesh was generated using a desktop workstation with a Xeon CPU, Nvidia Quadro GPU and 64Gb RAM. After 40 hours of processing, the final mesh consisted of 49 million faces. This model was then simplified to produce a "light" version formed of 4.9 million faces. All of these parts of the processing were produced using Agisoft Photoscan.

The presence of targets from the topographic network, easily recognizable in the aerial photos, allowed the geo-referencing of the photogrammetric model. Furthermore, the topographic survey allowed the joining and the integration of the different models generated by aerial and terrestrial photogrammetry and the 3D laser scanner survey. The 3D documentation was concentrated mainly on documenting the top part of the hill (Fig. 5), all along the medieval fortress; the existing cartography was used to generate a model of the lower part of the site, now completely covered by vegetation.

3.4 Terrestrial Photogrammetry

To complete the digital survey, terrestrial photogrammetry was undertaken in order to have a more detailed documentation of the remains of the main building (the two towers, the residential tower called *dongione*, and one of the houses once inside the *cassero*). This last survey campaign was conducted taking care to detect areas that the 3D laser scanner had not reached, such as the upper surfaces of the two overturned portions of the main tower (Fig. 6).

Figure 5. One of the many aerial shots from the mini-balloon: top view of the northern tower.

4. 3D DATA POST PROCESSING AND RECONSTRUCTION

After the completion of all the measurements, the set of data from the 3D laser scanner was treated using Leica Geosystem Cyclone software. The first phase of the data processing consisted of the alignment of the scans. This was done by connecting the scans each other, and singles or groups of them to the topographical network. Then the registered point cloud (Fig. 7) was imported into Bentley Pointools software and managed there for further data processing. This phase was aimed at the production of 2D representations of the site and of the architectural remains (Fig. 8 to 11). All the plan and section views were produced using Pointools and then completed and refined in Autodesk Autocad.

Figure 6. View of one of the main fragments of the northern tower.

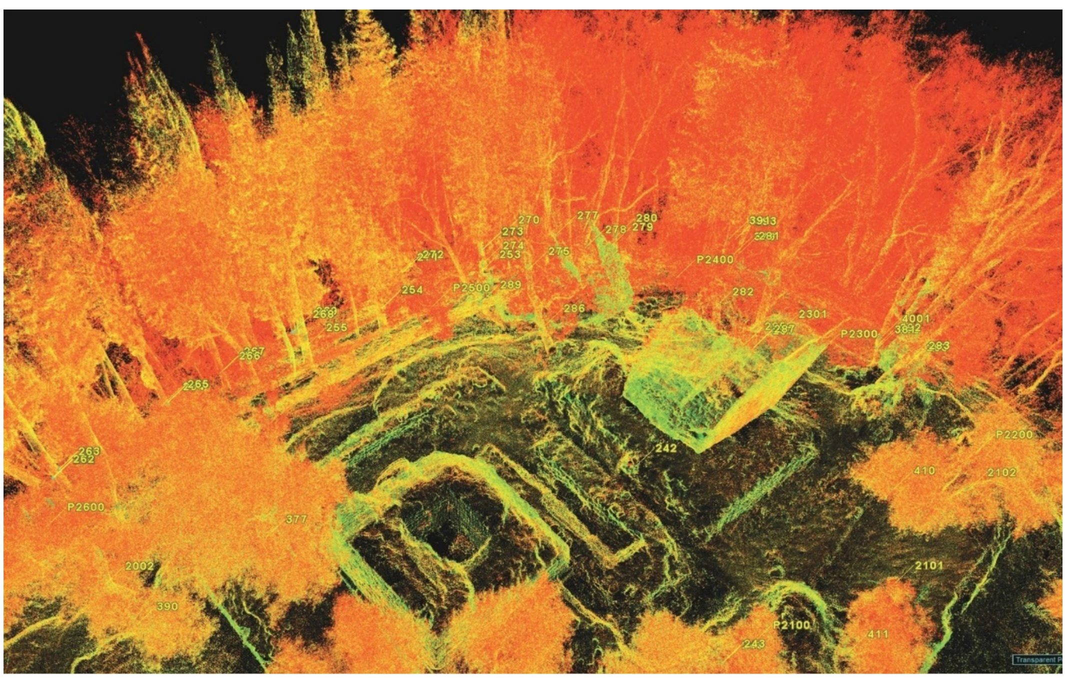

Figure 7. The general aligned point cloud from the 3D laser scanner survey, view of the northern tower.

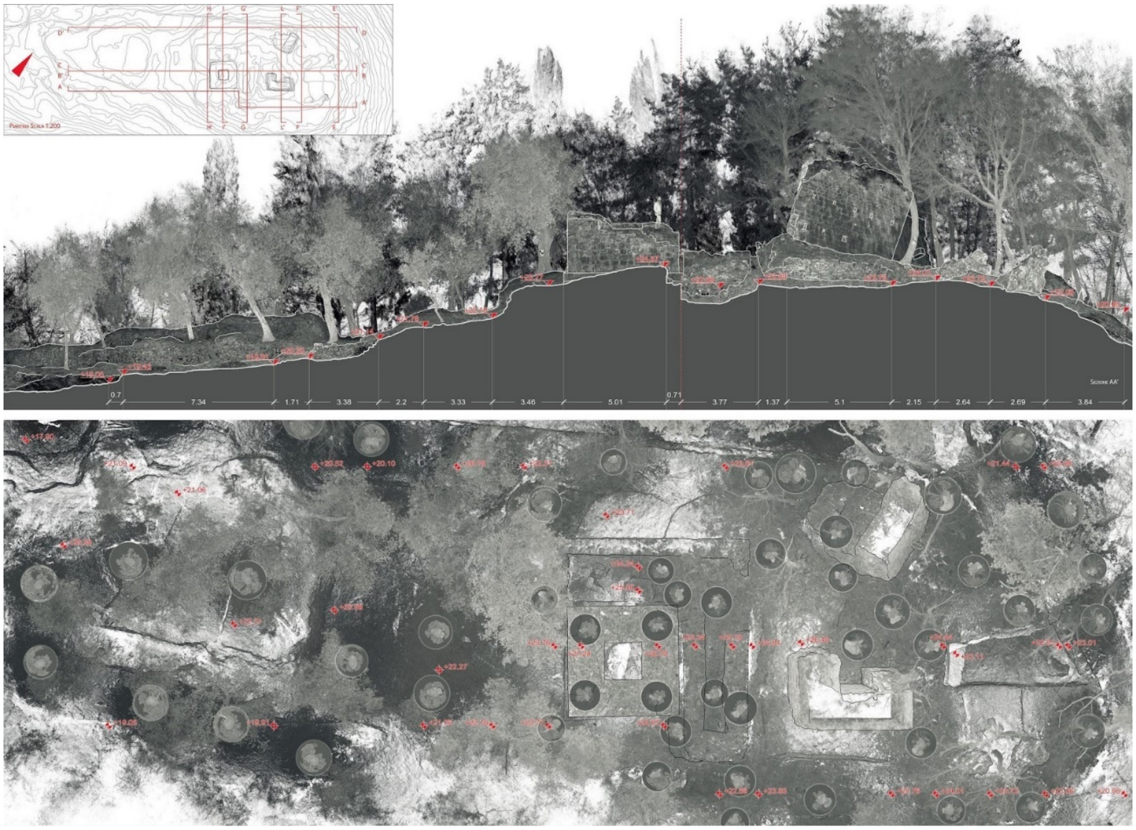

Figure 8. The northern tower, plan view and section.

This part of the work produced a general plan and a series of short sections on a scale of 1 to 200, and two long sections of the ridge on a scale of 1 to 500, in order to clearly document the trend of the hill.

Next, a series of plans and sections on a scale of 1 to 50 were produced. These were a good reference system, allowing us to analyze the remains of the northern tower, of the southwest area and of one of the *cassero* houses. The main focus fell on the remains of the main tower. It has a square plan, with a central compartment, also characterized by a square shape, which probably was used as a tank for collecting water, directly excavated in the foundation rock of the tower.

One of the two collapsed pieces has a monolith jutting about 50 cm, with a groove on one side. In order to have a more detailed representation of the ruins, further representations were made with a change of scale up to 1 to 20. This was done mainly using the models derived from the terrestrial photogrammetry (Fig. 12). This progressive approach to more and more detailed representations of the architectural remains allowed a better understanding and reading of the structures. Even if, at that time, the process of reconstruction had not begun, a certain reasoning about traces and evidences was ongoing.

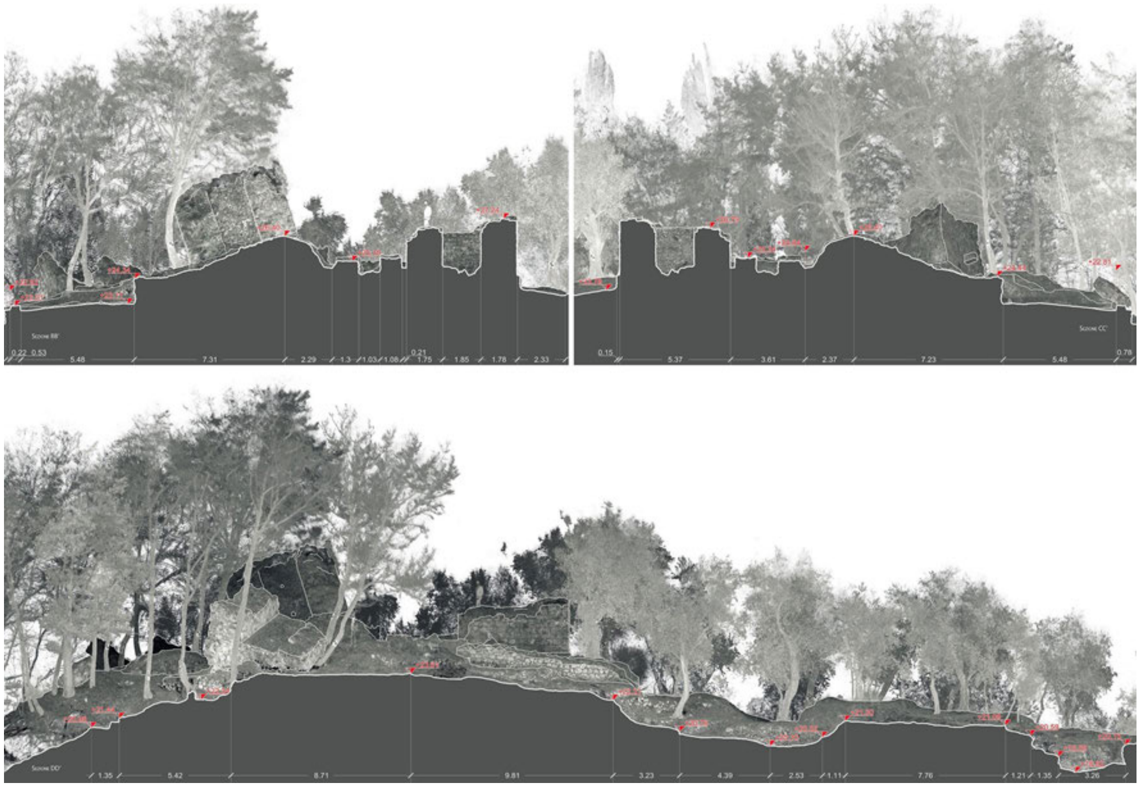

Figure 9. The northern tower, sections.

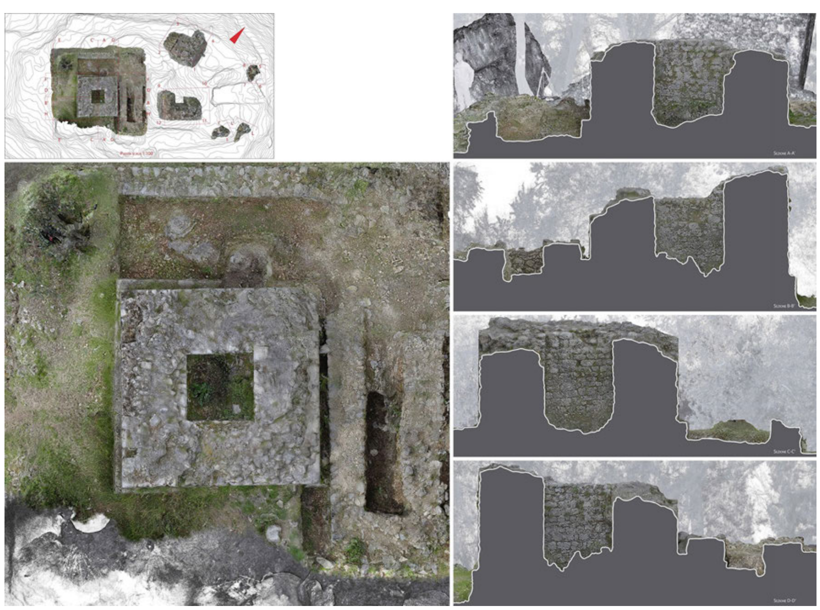

Figure 10. Results from the photogrammetry: the northern tower, plan view and sections.

Figure 11. Results from the photogrammetry: the northern tower, sections.

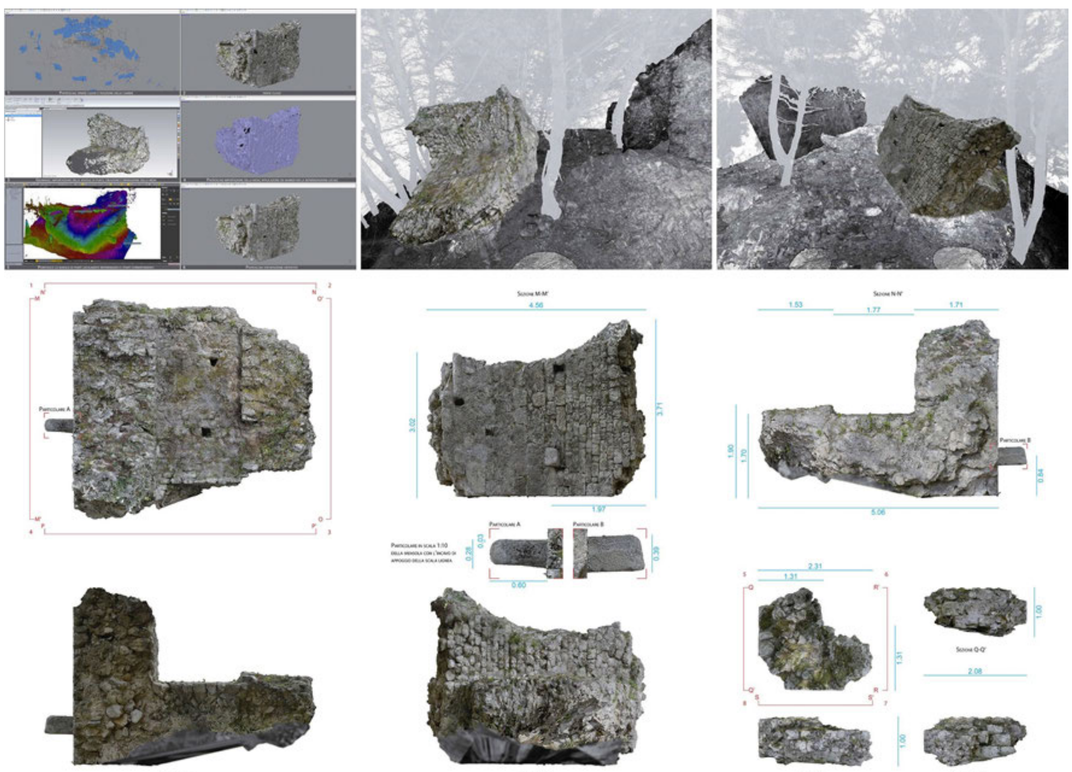

Figure 12. Results from the photogrammetry: fragments from the northern tower.

5. A PRINTED 3D MODEL AS AN EXPERIMENTAL TOOL

In order to formulate a reconstructive hypothesis of the main tower, it was considered useful to create physical models representing the ruins. The idea was to use these models to reassemble the tower, playing with the model to recreate all the possible combinations of the ancient collapse. This was done in order to better understand the former positions of the parts, the original height of the tower and the dynamics of the destruction.

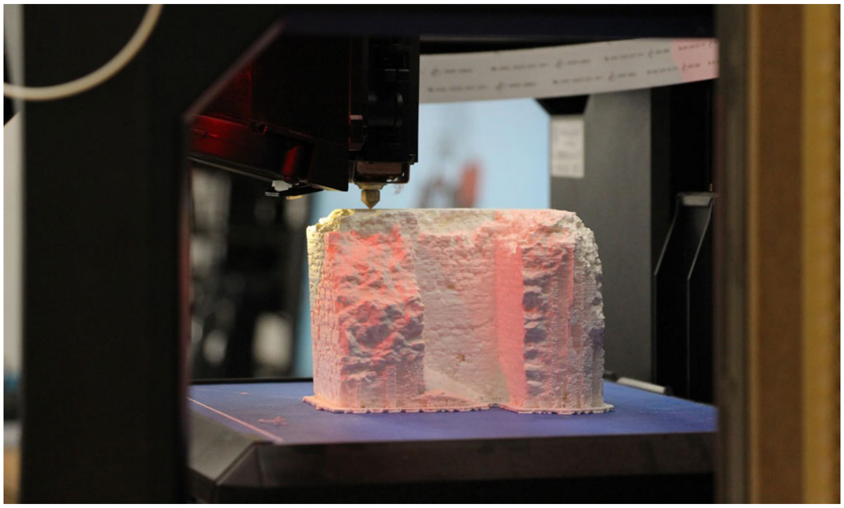

Figure 13. Printing in progress on one of the parts from the northern tower.

The most practical way to obtain this detailed model from such irregular shapes was by means of 3D printing [Evans 2012; Lipson and Kurman. 2013; Mongeon 2015; Lupton 2016]. An optimized set of meshes, with all the "holes" closed, various defects repaired, noise and sparse elements cleaned, was prepared for printing using Mcneel Rhinoceros 3D and MakerBot software.

The MakerBot 3D printing machine produces its models using a thin filament in PLA (prolactin), a biodegradable plastic obtained from corn protein. First, the machine makes a sort of preliminary mat (raft), to avoid possible sliding of the model in the press. Subsequently it realizes the external surface and the internal structure of the model. In this case, the honeycomb structure was chosen because it offers excellent resistance with a high speed of production. When needed, the machine was set up to create supports by printing less dense material at the bottom of the jutting or inclined elements, to avoid deformations of the object before its cooling. At the end of the printing process (Fig. 13), the models were manually cleaned from all the supports and preliminary raft.

Once the models of the pieces of the tower were ready, we carried out a series of tests for reassembling them. At first, we made many assumptions made. But after the first series of tests, it was considered preferable to define three main hypotheses, and for each case it was possible to understand the various movements that these pieces would have experienced, while collapsing, to reach their current locations. The match of the bodies split in two in the 1970s was perfect and left no doubt, while the relocation of this block on the base has been a subject of debate among archaeologists. But in the end, the ways of collapse described by the models showed the implausibility of two of the hypotheses, proving that the third one was correct.

It is important to underline how easy it was to handle these printed models, quickly finding the solution to the various hypotheses and defining the correct one in few minutes of work. The direct manipulation of the parts was so immediate and easy in the solution of this process that it led to a certain surprise in all the operators, but it cleared the field of any doubt about the sequence of the fall. In this way, all the parts were brought back to their original positions and the model guided the following digital reconstruction [Amico et al. 2013].

Operating with the physical model as a guide and reference turned out to be the best way to do this (Fig. 14); any other solution, like a direct repositioning of the digital model, was capable of leaving some doubts, because of the "inconsistency" of the polygonal meshes or perhaps because of the missing "weight" of the elements in the digital space. It is not possible to apply a generalization of the process, but in this case, the use of a 3D printed model tuned out to be a perfect solution in clearing the field of the various hypothesis about the sequence of the fall. The accurate survey found an excellent ally in the 3D printing process; the high level of details of almost all the borders and the realistic appearance of the models helped a lot in the manipulation process. A simpler model would not have been that efficient, while the low accuracy of the edges and a raw similarity between the real remains and the model would be too approximate to allow the testing to be successful. In summary, the sharp model made in PLA was easy to manipulate (lightweight, efficient in the matching of the borders, and of the right size to have a realistic tactile feedback). The model of the terrain was accurate enough, but at the same time simplified enough to both help the understanding of the fragment's movement on its surface and to give a reduction to the transformations occurred in time (soil movements, vegetation growth, partial falls).

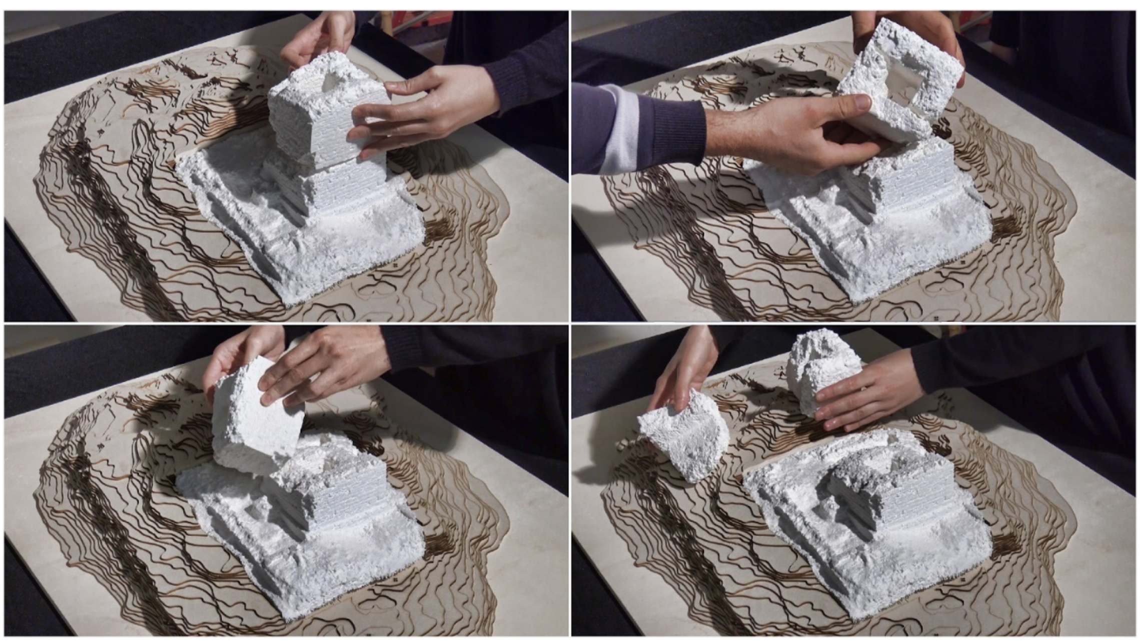

Figure 14. Operating various reconstruction tests on the 3D printed model of the northern tower.

Two videos illustrating the main sequence of the fall and the reconstruction operation based on the printed model can be viewed at the following links: https://youtu.be/64Vgar1h0gE and https://youtu.be/o15PEAse12M

Each case was then checked for an additional confirmation using the alignment of the partial orthophotographs of the tower (Fig. 15). This check was done to vanquish any possible doubt about the alignment results and to define a first base for further virtual reconstruction.

The higher level of details allowed by the texture rendering permitted us to bring on and complete the analysis and to make decisions about the original state of this architecture.

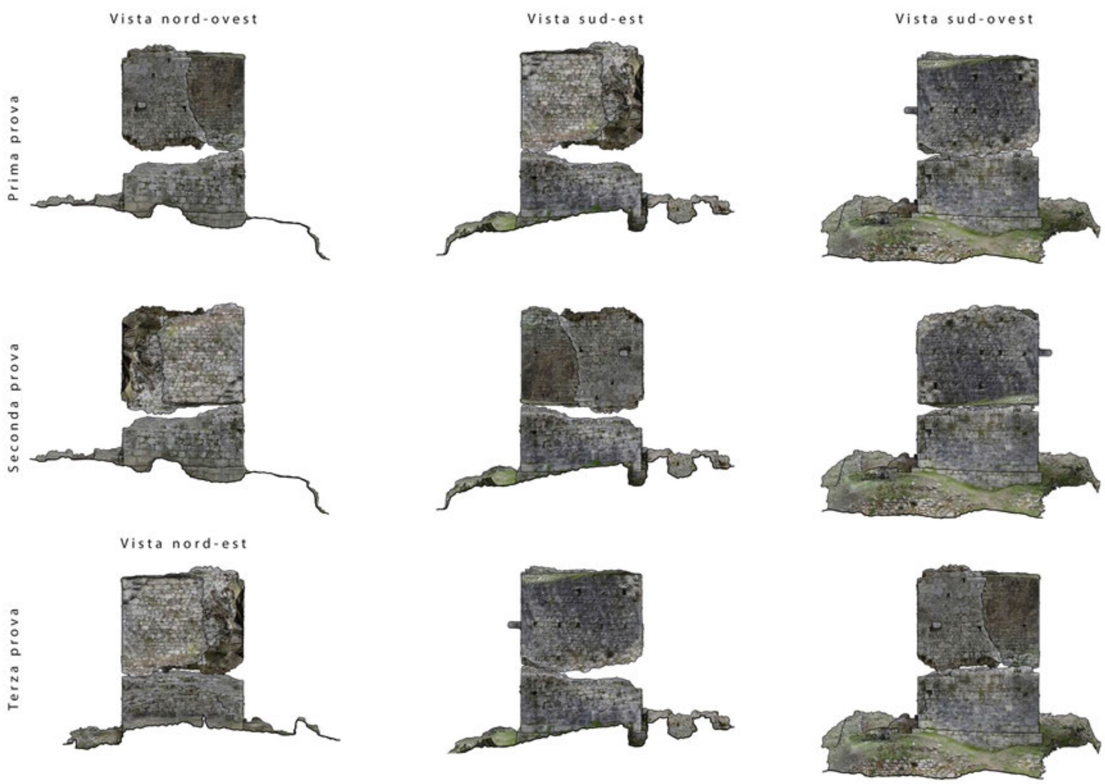

Figure 15. Operating various reconstruction tests on the photogrammetric model of the northern tower.

The third reconstructive hypothesis could find support in the fact that the scaffolding holes would be absent on the side that faces the guardhouse, while on the opposite side the scaffolding holes are numerous and well distributed, perhaps owing to the use of the guardhouse as a scaffold. Here the groove of the shelf is oriented upwards, with the idea of a stair resting on it. It is also possible to note a considerable lack of material between the base and the upper portion of the tower; this accords with the idea of a mine cut made on the side of the collapse. In fact, according to historical sources, when a tower was destroyed it was cut at the foot on one side. Wooden props were placed under the cut and when the props were set on fire, the tower fell down. In the end, the adopted hypothesis is the one with the shelf oriented to the west, because direction of the collapse is the most suitable to the position occupied by the two detached blocks. Therefore, it is possible to estimate that the fall occurred with a 180-degree overturning of the upper portion. Then the summit would have been detached and rolled downstream, while the sparse blocks would have been separated later.

After that, when analyzing the three blocks, a lack of openings was noticed, suggesting an entry from a high position (plausible for defensive purposes), and the fact that the tower was not inhabited by anyone (as suggested by the small size of the central compartment).

Thus, it is possible to say that this structure was a tower used for controlling the area, reachable by means of a retractable external wooden staircase. It probably rested on the shelf jutting from one of the two collapsed blocks, and the groove can be interpreted in this way.

The hypothesis of an inaccessible inside tower agrees with the idea that on the bottom of the tower there was a cistern, as suggested by the hollow partly covered by vegetation, and by the parallel with the solution adopted at the nearby castle of Peralla, where it is possible to find a similar presence of a tower-tank. Thinking about the function of control and defense of the towers, and about their use as reporting points with fires and mirrors, it is possible to suppose a wooden catwalk on the top, from which one could to collect water from the cistern with a bucket (Fig. 16).

In the end, knowing the height of the shelf, we can estimate that the original height of the tower was around 12 m.

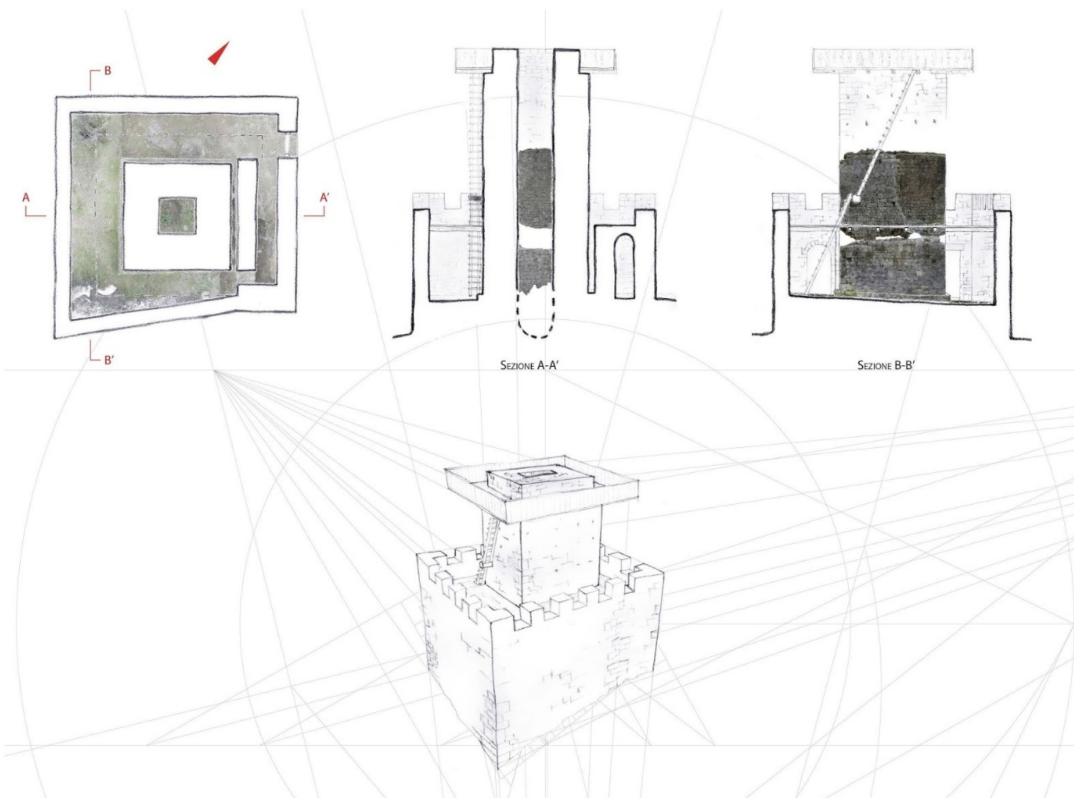

Figure 16. Draft reconstruction of the northern tower.

The second tower was probably similar to this one, while the dungeon, larger and inhabited, was likely lower.

In order to have an overall representation of the medieval *cassero*, a digital model of the whole hill was developed, cleared of trees. This was done using the level curves from the top of the hill, producing horizontal sections every half meter using Bentley Pointools snapshots. Then the curves were used for creating the surface of the current state of the ground. In addition, where the curves were thicker, we noticed some areas with regular boundaries, excavated into the rock of the hill. Probably they are traces of dwellings. A map of the houses of the *cassero* was developed from these traces, allowing us to complete the volumetric reconstruction of the top of the hill.

Figure 17. Digital reconstruction of the whole settlement of Montecastrese (modeling and rendering by Panaiotis Kruklidis).

6. THE MUSEUM IN CAMAIORE

The results of this research have deepened the study previously undertaken by the Archaeological Group of Camaiore. A selection of products developed in our research, like the physical models and the virtual reconstructions, are on permanent exhibition in Camaiore at the Civico Museo Archeologico, Palazzo Tori-Massoni, Piazza Francigena. The main materials in the exhibition are a series of panels, some multimedia elements, a laser cut model showing the general reconstruction of Montecastrese and another one showing its actual state. The models were realized in white Plexiglas with a digital laser cutting machine at the Architecture Modeling Laboratory (LMA), part of the DiDALabs System of the Dipartimento di Architettura, University of Florence. The idea was to produce a physical model accessible to the public, usable as a tactile model when needed, robust and massive enough and capable of communicating the relationship between the territory and the structures (both in the form of the archaeological site and of hypothetical reconstruction).

These elements found their accessible place among the rich collection of objects on display at the Civic Museum, planned and designed by architects Andrea Innocenzo Volpe and Yoichi Sakasegawa. The whole set of materials about Montecastrese is presented in order to direct the public's attention to a medieval site that deserves to be better known after falling into oblivion owing to centuries of total abandonment.

Figure 18. Digital reconstruction of the northern tower at Montecastrese (rendering by Panaiotis Kruklidis).

7. CONCLUSIONS

Beginning with a complete and accurate digital survey, a whole process of cultural dissemination was undertaken, creating, at the same time, an appropriate base for new studies and research to enhance the knowledge and understanding of this ancient citadel. From its beginning, this was the aim of our research, focusing on the evidence and traces coming from the remains of this long-abandoned place.

All these elements were the basis to develop, with well-calibrated steps, an attempt to introduce 3D printing as an integral part of the virtual reconstruction process. It seemed appropriate to conduct the case study in this way, while the approach based on a physical, scaled model seemed the most efficient method for understanding a complicated situation where both the strategy of the destruction and the original aspect of the architecture were subjects of interest.

Finally, as often happens when all the steps are done and some clear results begin to emerge, the rich system of references, surveys, reconstructions, pictures, sketches, tests, etc. seemed to be immediately ready to be transformed into panels, models, multimedia and other dissemination products, able to present the great importance of a cultural heritage site, long-ago destroyed but brought back by advanced 3D digital technologies into a new kind of existence in 2016, almost eight centuries after its disappearance.

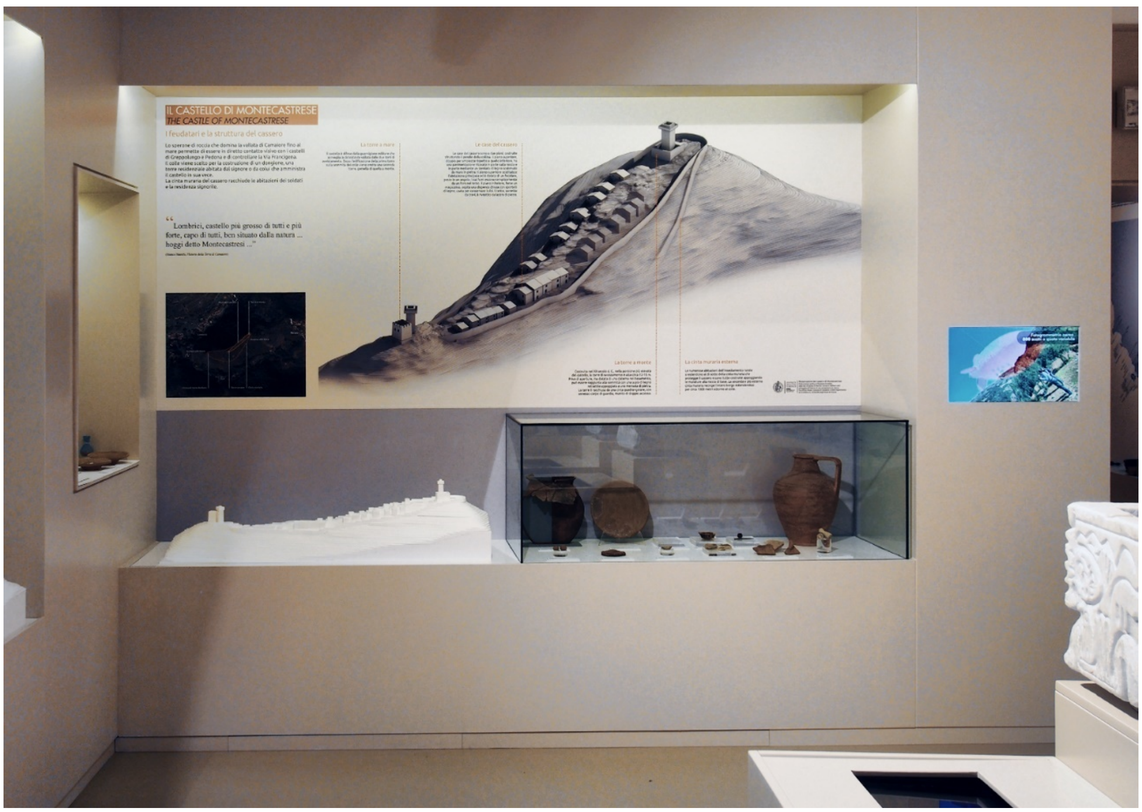

Figure 18. One of the spaces dedicated to the Montecastrese settlement inside the Civico Museo Archeologico in Camaiore.

8. REFERENCES

Nicola Amico et al. 2013. Quality Management of 3D Cultural Heritage Replicas with CIDOC-CRM. In *CRMEX 2013 Practical Experiences with CIDOC CRM and its Extensions. Proceedings of the Workshop*, Malta, 61-69.

R. Antonelli. 1995. Bianco Bianchi Cronista del '500, Lucca: Matteoni Stampatore.
Gabriele Bitelli, et al. 2007. The Potential of 3D Techniques for Cultural Heritage Object Documentation. In Jean Angelo Beraldin et al., eds. *Videometrics IX, Proceedings of Electronic Imaging Science and Technology (SPIE)*, 64910S1 - 64910S10.
Brian Evans. 2012. Practical 3D Printers: The Science and Art of 3D Printing, New York: Apress L.P.
Gabriele Gattiglia and F. Anichini. 2009. La Versilia nel Medioevo. Ricerche Archeologiche in un'Area Buia della Toscana Settentrionale. *Atti del V Congresso Nazionale di Archeologia Medievale* Foggia-Manfredonia 30.09-03.10 2009, Firenze 2009, 268-273.
Gabriele Gattiglia and G. Tarantino. 2013. …Loco ubi dicitur castello. Montecastrese e l'incastellamento in Versilia. *Archeologia Medievale* XL (2013), 233-257.
Hod Lipson and Melba Kurman. 2013. Fabricated: The New World of 3D Printing. Hoboken (NJ): John Wiley & Sons.
D. Lupton. 2016, 3D Printing Technologies: Social Perspectives, Working Paper in Researchgate.com and Academia.edu.
Bridgette Mongeon. 2015. 3D Technology in Fine Art and Craft: Exploring 3D Printing, Scanning, Sculpting and Milling. Boca Raton (FL): CRC Press.
F. Panero and G. Pinto. 2009. Castelli e fortezze nelle città e nei centri minori italiani (secoli XIII - XV). In *Atti del convegno svoltosi a Cherasco sede del CISIM*, 2008. Cherasco 2009.
L. Santini. 2002. Montecastrese e gli altri castelli di età feudale del territorio di Camaiore, Massarosa (Lucca): Tipografia Massarosa Offset.
Florio, E. Stortoni, ed. 1993. I castelli feudali del territorio di Camaiore, Sarzana: Industria Grafica Zappa Sarzana.

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