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New geophysical and archaeological investigations at the Nunziatella site in Mascali, Mount Etna (Italy)

Stefano Branca[*,1], Maria Grasso[2], Valerio Materni[3], Angela Merendino[4], Vincenzo Sapia[3], Leonardo Vaccaro[5]

(1) Istituto Nazionale di Geofisica e Vulcanologia – Osservatorio Etneo, Catania, Italy
(2) Archeoclub d'Italia, area ionico-etnea, Giarre (CT), Italy
(3) Istituto Nazionale di Geofisica e Vulcanologia – Sezione Roma2, Italy
(4) Soprintendenza ai Beni Culturali di Catania, Regione Siciliana, Catania, Italy
(5) Associazione Mascali 1928, Mascali (CT), Italy

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Abstract

Etna volcano is characterized by a rich presence of archaeological sites documenting uninterrupted human activity along its lower flanks since the Greek colonization (734/735 B.C.) in Sicily. Within this context is the Nunziatella site in Mascali territory, located on the lower eastern flank of Etna, an area favoured for human settlement by the presence of water sources. The Nunziatella site is known for housing the medieval church of Maria Santissima Annunziata (12th century A.D.) and a small Paleo-Christian basilica (5th-6th century A.D.), but clues suggested the presence of additional buried structures. To better investigate the Nunziatella site, an interdisciplinary study was conducted, combining non-invasive geophysical surveys (GPR), archaeological excavations and C^{14} dating. GPR results revealed an elongated anomaly with a defined geometry south of the church, hypothesizing buried structures at 0.5-2 meters depth. The geophysical surveys proved to be a fundamental tool for guiding the excavations. The archaeological excavations confirmed the existence of a building, bringing to light a wall over nine meters-long parallel to the church's south facade, featuring interior plaster and a *cocciopesto* floor at the base that is characterized by the presence of two pits. These latter have revealed numerous fragments of ceramics, tiles and pottery of Byzantine era confirmed by the C^{14} age of a bone fragment (663-775 A.D.). The pits refer to a phase of abandonment of the building whose construction took place in an era certainly prior to the 8th/9th century A.D. This new data allows us to hypothesize the presence in this area of a large Late Roman-Byzantine monumental complex of unknown function confirming the historical importance of the Nunziatella site since ancient time.

Keywords: Etna; Nunziatella; Geology; GPR investigation; Byzantine archaeology

1. Introduction

The fertile territory of Nunziata di Mascali, situated in a privileged position on the eastern coast of Mount Etna, was populated since the most remote antiquity, as evidenced by traces of settlements dating back to the final period of the Early Bronze Age (Privitera, 2015) and numerous archaeological finds from the Hellenistic (Privitera and Grasso, 2012), Roman (Orsi, 1930), and Byzantine periods (Lentini, 1982). Among these areas, the most important is that of Nunziatella (Buda, 2015), which encompasses a Paleo-Christian basilica and the adjacent current worship building. Despite its modest late 19th-century single-nave exterior, this building actually has Norman origins. Its first construction dates to that era when the territory of Mascali, liberated from the Arabs, was donated by Roger II of Sicily (ca 1095-1154) to Ansgerio, the Benedictine Bishop of Catania. In this context, the medieval church and the Priory of the "Santissima Maria Annunciata" in Mascali arose. As testimony to this, the dome of the apse features a dominant Norman representation of Christ Pantocrator (from the Greek παντοκράτωρ, "All-powerful") seated on a throne and enclosed within an almond shape supported by four nimbate angels. At the extremities of the apsidal conch, two other fresco fragments survive: on the left, the nimbate head of a saint, and on the right, the Mother of God with Child, bearing a cruciform nimbus. In 2012, in the immediate vicinity of the current church, archaeological excavations brought to light the remains of a mono-apsidal basilica with three naves divided by pillars, following an architectural typology that originated in Constantinople and was well attested between the 5th and 6th centuries A.D. The building preserves two mosaic pavements with polychrome tesserae. The presbytery mosaic, though heavily damaged, depicted a kantharos or a fountain (the source of Life), where peacocks and fawns came to drink. In the central part of the main nave, a nearly intact mosaic is preserved, featuring marine subjects (octopuses, cuttlefish, fish) arranged according to a geometric scheme and surrounded by an external band decorated with knotted circles, with birds, fish, and, at the four corners, small kantharoi. The basilica, with some doubt due to the lack of certain proof, has been associated with the Monastery of S. Andrea, located "super Maschalas" and mentioned in a letter sent by Pope Gregory the Great (590-610) to Secondino, Bishop of Taormina (Buda, 2015). Finally, in November 2021, during the archaeological surveillance by the Superintendence of Catania, while laying a manhole for fibre optics,

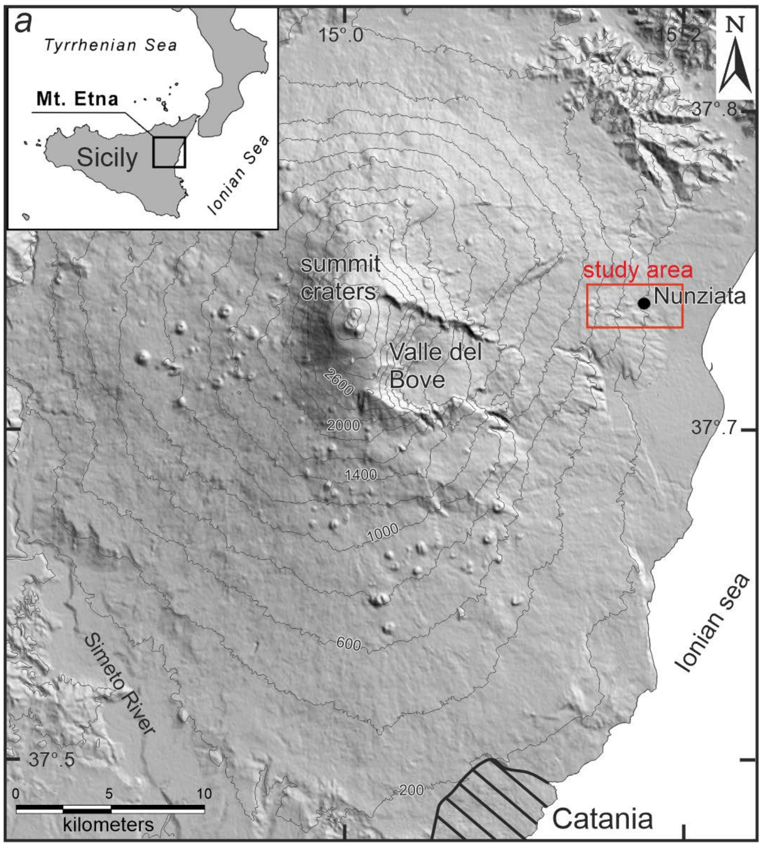

Figure 1. Location of the study area. Digital Terrain Model of the Mount Etna volcano, with contour lines in meters.

a portion of a sepulchral area was discovered in the open space in front of the church of Maria Santissima Annunziata, situated at a depth between −0.85 and −0.95 meters from the road level. The importance of the site and these new discoveries have prompted resuming investigations through an interdisciplinary approach. In order to develop knowledge on this important archaeological site of the Etna region, an interdisciplinary study was performed through new geophysical and archaeological investigations and C^{14} dating. In particular, ground penetrating radar (GPR) surveys were undertaken in the external area of the mediaeval church. Through this non-destructive geophysical technique, it was possible to obtain high resolution images of buried structures preparatory to carrying out archaeological excavation tests (Fig. 1).

2. Geological and hydrogeological setting

The archaeological site of Nunziatella is located in the lower northeast flank of Etna volcano at an altitude of 230 m. In this area the relicts of ancient lava flows related to the Timpe phase of Branca et al. (2011a, b) discontinuously outcrop. These lava flows rest on the sedimentary basement consisting of a small outcrop of varicoloured clays with chaotic texture of Upper Cretaceous (Argille Varicolori Antisicilidi of Branca et al., 2011a). The oldest Timpe lava flows formed an isolated morphological relief made of massive lava flows, highly porphyritic with xenocrysts of olivine and pyroxene, outcropping immediately westward of the Nunziata village (Fig. 2). These lava flows, dated 180.2 ± 19.2 ka (De Beni et al., 2011; Branca et al., 2011b), show a mm-thick alteration patina and are frequently disarticulated in large blocks. Conversely, a lava succession composed of several highly eroded superimposed massive lava flows outcrops immediately southward of the Nunziata village (Fig. 2). These lava flows, dated 126.4 ± 4.8 ka (De Beni et al., 2011; Branca et al., 2011b), present a high variability of lithology showing texture ranging from sub-aphyric to porphyritic with variable amounts of pl, px and ol phenocrysts. The lava succession is widely covered by a 10 m-thick succession of pyroclastic fall deposits composed of ash and scoriaceous lapilli interbedded with yellow eolian silty deposits and black sandy beds (Tagliaborsa member of Branca et al., 2011a). These tephra layers were generated by strombolian and subplinian eruptions during the activity of the Ellittico volcano occurring between 60 and 15 ka ago (Stratovolcano phase of Branca et al., 2011a, b). The Ellittico pyroclastic succession is covered by the volcanic products generated by the eruptive activity of the last 15 ka related to the Mongibello volcano (Stratovolcano phase of Branca et al., 2011a, b). In the study area, the

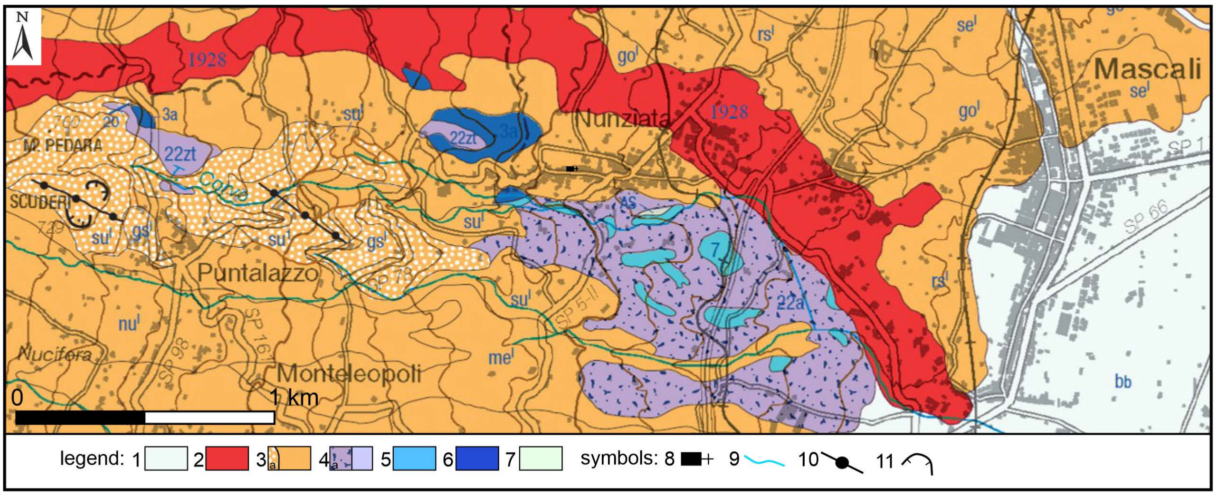

Figure 2. Geological map of the study area from Branca et al. (2011a). Legend: 1) Recent coastal alluvial deposits; Mongibello volcano: 2) 1928 lava flow; 3) lava flows scoria cones (a) of the period 15-3.9 ka B.P.; 4) Ellittico volcano: lava flows and pyroclastic succession (a) ranging in age from 60 ka to 15 ka B.P.; Timpe phase: 5) lava flows dated 126.4 ± 4.8 ka B.P.; 6) lava flows dated 180.2 ± 19.2 ka B.P.; 7) Varicoloured clays of Upper Cretaceous; Symbols: 8) church of Maria Santissima Annunziata; 9) drainage pattern; 10) eruptive fissure; 11) crater rim. The acronyms in the map correspond to the following lava flows: nu = Nunziata; me = Monteleopoli; su = Mt. Scuderi; rs = Ripa Saldara; go = Gona; se = C.da Saette; gs = generic scoria cone.

Mongibello volcano products are represented by two main eruptive fissure systems of Mt. Pedara and Mt. Scuderi that outcrop westward of the Nunziata village (Fig. 2). In particular, the eruptive fissure of Mt. Pedara consists of the remains of a phreatomagmatic deposit that is partially covered by the eruptive fissure of Mt. Scuderi formed by two segments with a left en-echelon arrangement, NNW-SSE oriented, located at 600 and 400 m a.s.l. and dated between 15 and 12.2 ka ago (Branca et al., 2011a). The Mt. Scuderi fissure generated a porphyritic light-grey lava flow, with abundant phenocrysts of amph, px and pl, discontinuously outcropping between Puntalazzo and Nunziata villages. The Mt. Scuderi lava flow is locally covered by a thin debris flow deposit and is heavily eroded along the river bed of the Corvo Torrent. The Mt. Pedara and Mt. Scuderi products are partially covered by the lava field of Ripa Saldara (Fig. 2) that was generated by an eruptive fissure, ENE-WSW oriented, made of a welded spatter rampart located at 1850 m a.s.l. close to Mt. Frumento delle Concazze. The Ripa Saldara lava field is dated 5240 ± 50 BP (Lanzafame et al., 1997), corresponding to 3290 ± 50 B.C., and extends on the lower NE flank for a maximum length of 11.9 km. This lava is widely covered by 1 m thick pyroclastic and epiclastic deposits in the area of Nunziata where the frontal portion of the field that is partially covered by the 1928 lava flow is located.

On the whole, the thickness of the volcanic pile in this sector of the volcano ranges from 0 up to 200 m due to the presence of an E-W oriented morphological relief of the sedimentary basement, the so-called Vena ridge of Branca and Ferrara (2013). This sedimentary ridge formed by Upper Cretaceous clay conditioned the hydrogeological setting of this area that is characterized by a shallow groundwater circulation with a flow of about 2-3 L/s (Branca and Ferrara, 2001) exploited through several drainage tunnels. Some springs are present along the Corvo Torrent, at about 300 m a.s.l., emerging at the interface between the lava cover and the Upper Cretaceous clay and in the river engraving immediately southward (Fig. 2).

3. GPR surveys

3.1 Method

Ground Penetrating Radar (GPR) is a non-invasive geophysical technique based on the propagation of electromagnetic pulses, typically within the frequency range of 10 to 2500 MHz. The method exploits the reflections of electromagnetic waves caused by subsurface discontinuities that alter the dielectric properties of the material. GPR is a highly effective tool for high-resolution imaging of the uppermost subsurface layers, with the capacity to generate both two-dimensional (B-SCAN) and three-dimensional (C-SCAN) representations of the surveyed areas.

In archaeological investigations, GPR proves invaluable by facilitating the rapid and cost-effective exploration of large areas. Buried structures, such as walls, columns and cavities, induce significant dielectric contrasts, which are manifested as prominent reflections in radar profiles. These are frequently accompanied by hyperbolic diffraction patterns, enabling the identification of such structures in the subsurface. As a result, GPR is widely recognized as one of the most efficient non-invasive techniques in archaeological research, playing a fundamental role in the preliminary planning of excavation activities (Basile et al., 2000; Goodman and Piro, 2013).

The most commonly used representation of GPR data in archaeological surveys is through C-SCAN images, also known as time-slice maps (Goodman et al., 1995; Conyers and Goodman, 1997). This methodology is based on representing variations in the amplitude of the electromagnetic signal through horizontal sections at specific depth intervals. By correlating reflection amplitudes recorded at consistent time intervals, this method facilitates the creation of 3D models of the subsurface, thereby enabling the identification of spatial patterns and the organization of detected anomalies along distinct geometrical alignments.

The selection of an appropriate antenna for GPR surveys is a critical aspect that influences both penetration depth and resolution. The optimal antenna choice depends on a balance between these two parameters, as well as on the dimensions of the target and the specific properties of the subsurface under investigation (Annan and Cosway, 1994). Generally, low-frequency antennas (10-400 MHz) provide greater penetration depth but lower resolution, whereas high-frequency antennas (500-2500 MHz) yield higher resolution at the cost of reduced penetration depth.

3.2 Instrumentation, Data Acquisition Procedure and Data Processing

For this study, a Ground Penetrating Radar (GPR) survey was conducted using an IDS Hi-Mod system equipped with a dual-band antenna operating in the 400-900 MHz frequencies. Data processing was performed using GRED HD software (I.D.S. Georadar, 2018). The analysis revealed that increasing the operating frequency resulted in a significant reduction in penetration depth, with a marked decrease in the signal-to-noise ratio observed at depths exceeding 50 cm. Consequently, for the detection and analysis of anomalies, profiles acquired with the 400 MHz antenna were preferred.

The acquired data were georeferenced using a differential GPS system, which, when coverage was available, provided an average positional accuracy in the order of one centimetre.

For the survey conducted within the church courtyard (Fig. 3), the GPR data were collected following a pseudo-regular acquisition grid (12 m × 3.5 m). A parallel-line grid was established with a consistent spacing of 0.5 meters; however, the lengths of the survey lines varied due to the presence of obstacles in the survey area, such as construction material deposits. In total, 24 GPR profiles were acquired along the Y-axis (denoted as T), and 7 profiles were collected along the X-axis.

3.3 Instrumental Acquisition Parameters and Data Processing

The instrumental acquisition parameters, defining both temporal and spatial resolution, included a sampling window of 80 ns for the 400 MHz frequency and 40 ns for the 900 MHz frequency, with a total of 512 samples per scan for each frequency. The analysis of diffraction hyperbolas enabled estimating the average electromagnetic wave

Figure 3. Location of the GPR survey conducted within the church courtyard (area marked by the yellow box). 1) Medieval church of Maria Santissima Annunziata; 2) Paleo-Christian basilica.

propagation velocity, yielding a value of 0.09 m/ns. The effective investigation depth achieved with the 400 MHz frequency antenna was approximately 2 meters from the surface.

The data processing workflow included the following steps (Conyers and Goodman, 1997; Goodman and Piro, 2013):

(i) Time-zero correction
(ii) Vertical band-pass filtering
(iii) Horizontal high-pass filtering
(iv) Deconvolution
(v) Gain curve optimization
(vi) Kirchhoff migration.

Due to the acquisition methodology (parallel profile grid), the processed data were visualized as C-SCAN maps, constructed by averaging the amplitude and/or the squared amplitude of the radar signal within consecutive time windows of width Δt.

3.4 Results

The study area was significantly affected by various anthropogenic alterations accumulated over the years, including the presence of pipelines, inspection shafts, and structural elements, which complicated the interpretation of the obtained results. The analysis therefore began with the examination of 2D sections, evaluating the alignment and consistency of anomalies across parallel and perpendicular profiles. Subsequently, their spatial distribution was analysed in 3D sections based on shape and intensity.

Among the acquired 2D sections, Fig. 4 displays a set of eight B-scans that clearly highlight characteristic reflection patterns, with particularly notable high-energy anomalies. The B-scans display a distinct concentration of dielectric contrasts within the horizontal range of 0.5 m to 1.5 m and at depths between 0.5 m and 2 m. This concentration is indicative of variations in the physical and compositional properties of the subsurface materials, as delineated by the yellow dashed box in Fig. 4.

Despite the heterogeneity of the area, the processing of horizontal time-slice maps for the investigated site revealed that the distribution of the primary anomalies follows a well-defined geometry, aligned along a SW-NE direction (Fig. 5).

The slice at 0.8 meters clearly highlights the presence and orientation of this anomaly, which extends between $x = 1$ m and $x = 9$ m. It is characterized by high intensity and coherence, with a discontinuity occurring between $x = 6.5$ m and $x = 7.5$ m (later confirmed through excavation to be a modern-era drainage channel constructed for water conveyance). Further analysis in the 1.0 m slice confirms the persistence of this feature up to $x = 6$ m, beyond which the anomaly decreases in both intensity and coherence, suggesting possible degradation or structural incoherence (Conyers, 2015).

Excavation operations have revealed, at approximately 1.1 m below ground level, the gap between the wall structure and the floor level, as well as multiple phases of remodelling that have occurred over the years.

To establish a correspondence between these anomalies and the features observed in the time-slice maps, two profiles, T6 and T19, were selected at x-coordinates of 3 m and 9.5 m, respectively (Fig. 5). The high amplitude and spatial distribution of the recorded anomalies indicated the possible presence of construction materials, a hypothesis later validated through archaeological excavation, which confirmed these anomalies as remnants of buried structures.

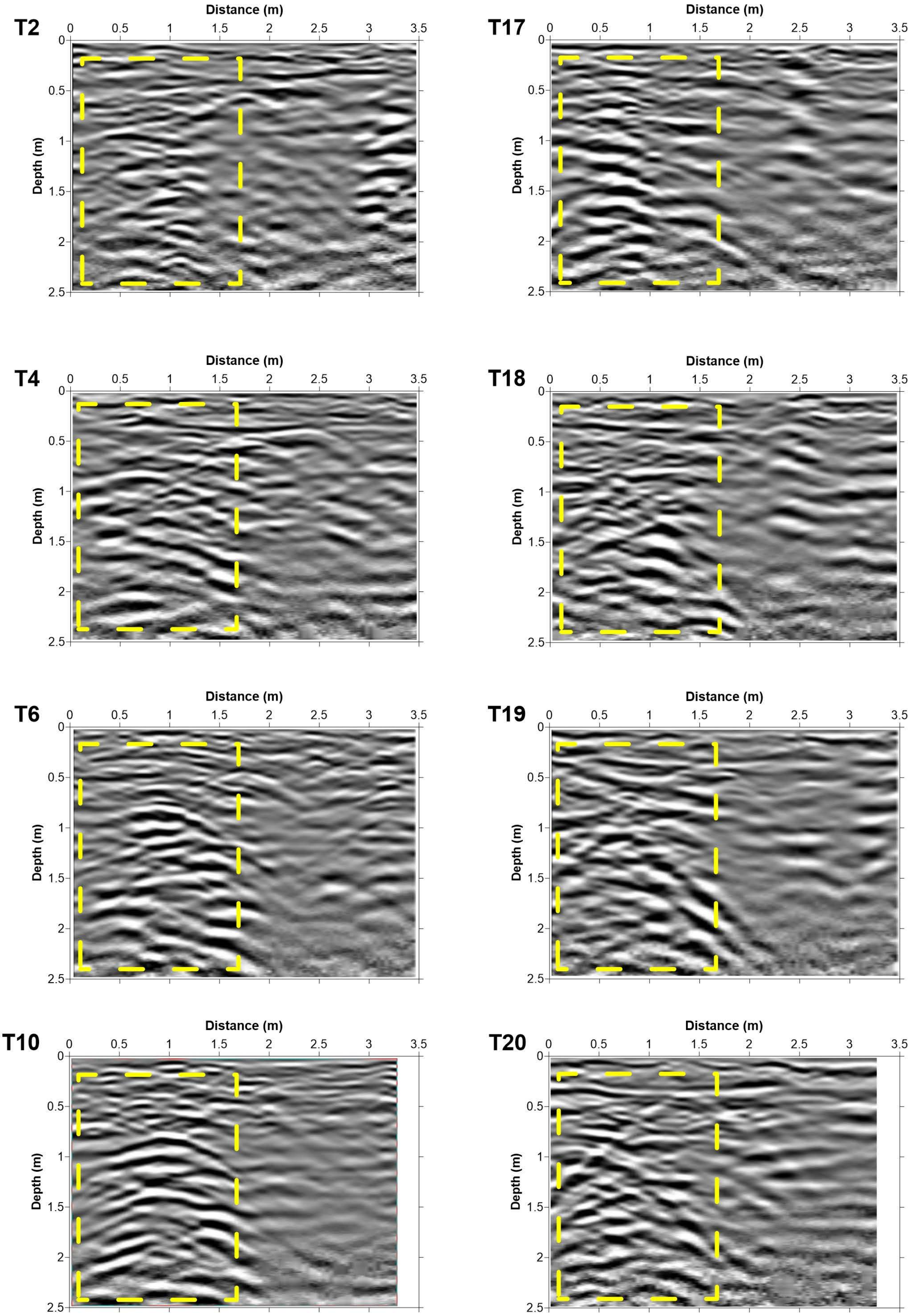

Figure 4. B-scan showing distinctive reflection patterns, with anomalies of high energy intensity (yellow box)

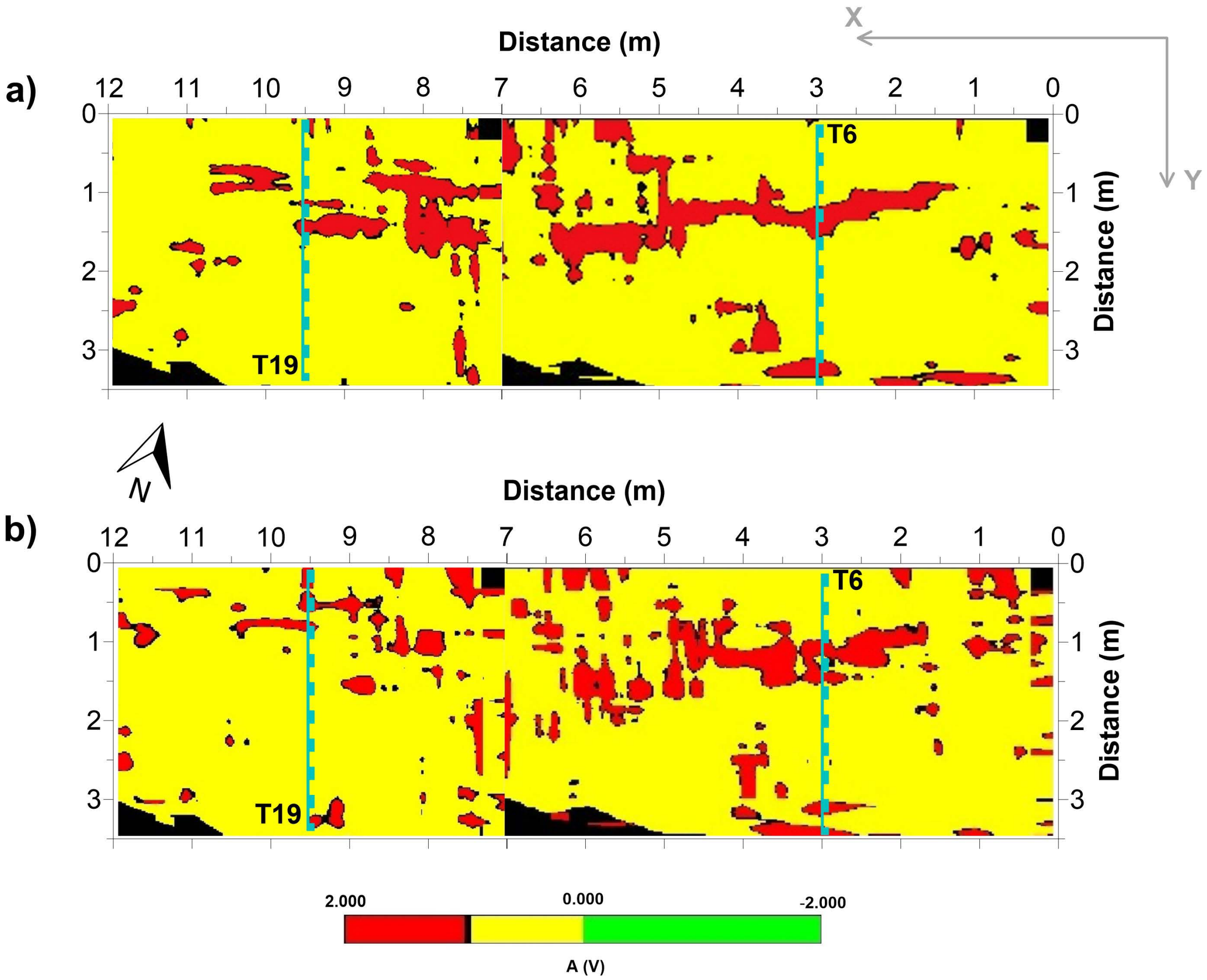

Figure 5. GPR time-slices computed from different two-way travel time windows (respectively between 18 and 22 ns for Fig. 5-a and Fig. 5-b). A constant electromagnetic wave velocity of 0.09 m/ns was adopted for time-to-depth conversion, resulting in corresponding depths of approximately 0.8 m for Fig. 5-a and 1.0 m for Fig. 5-b.

4. Archaeological excavations

The archaeological excavation focused on the fenced area south of the Church of Maria Santissima Annunziata based on the results of GPR prospections that highlighted an anomaly considered particularly significant in this area and confirmed by the archival documents preserved at the Soprintendenza Beni Culturali Ambientali of Catania. In particular, as stated in a 1989 Survey and Census of Cultural Heritage by the Municipality of Mascali, this wall and its parallel, still visible on the north side of the current church, have been considered the ancient external walls of the original building, chronologically ascribed to the 11th/12th centuries. Subsequently, Campo (2024) identified in these walls the base structures of the *cenobium* which he believed to be that of "San Giovanni di Ysigiro seu de Psycro vel Psoyero" near Mascali cited in medieval sources, although there are also different interpretations on the position of this building in the territory. This issue then re-emerged during the archaeological investigations carried out in 2012, focused on inside the current Church and on the external north side, where a Paleo-Christian basilica with a mosaic floor was brought to light (Taormina, 2015). On the south side of the courtyard, no control excavation was performed, but the new discoveries required reconsidering the relationship between the current church of medieval foundation and the small Paleo-Christian basilica, and, therefore, also a re-evaluation of the wall sections brought to light in the 1980s to the north and south of the current ecclesiastical building. Buda (2015), by coordinating old and new information, observing the alignments of the apses and wall structures, hypothesizes that "the current church of Nunziatella overlays the central nave of a previous three-nave church, contiguous to the smaller Paleo-Christian basilica," whose northern wall would coincide with that which closed off the left nave of the Paleo-Christian building. These interesting considerations, combined with the perplexities raised by a *cocciopesto* floor seen also in the 1980s in the area outside the church and then identified inside it during the 2012 excavations (Taormina, 2015), convinced us to reopen the excavation in the area south of the church. The choice, also advised by practical reasons such as the convenient presence of a high fence, seemed nevertheless challenging because it involved resuming investigations in an area already excavated. Indeed, the excavation proved very arduous and time-consuming, but in the end it allowed us to add some interesting information to what was already known.

4.1 The Excavation Campaigns

Within this study two excavation campaigns have been carried out so far. The first, between October and December 2023, mainly involved the fenced courtyard south of the current church where initially a long and narrow excavation trench was opened, defined as Test Pit one (S. I.), of approximately regular shape (approx. 9 × 2 m). The second campaign began on October 26, 2024, with the expansion of S. I. to the west (Extension III west) and to the east (Extension IV east) (Fig. 6).

The excavation proved particularly complicated both due to the narrowness of the movement spaces around and within the excavation area – among other things, a disused manhole and a water pipeline were still in use – and due to the removal of the filling layers related to the arrangements of the area carried out in the 1980s (Marano, 2012). In fact, under the modern walking surface there was a more or less thick layer consisting of waste material of various nature, practically sterile, which had completely replaced the original fill. The discovery of a can with an expiry date of 1989 dated the stratigraphic unit without a shadow of a doubt. In the north-eastern side of the trench, this level covers a channel (USM 2) coinciding with the approximately curvilinear structure present in the 1980s planimetry, while to the south a long plastered wall with an east-west orientation (USM 1) emerged (Fig. 6), coinciding with that already partially documented and mentioned in the bibliography. The first filling level, with the exception of some holes related to the laying of utilities, covered, besides the channel and the wall, a layer of black and soft earth (US 8), rich in re-mixed ancient and modern fragments and dated by the presence of another can, also with a 1989 expiry date, and a series of plastic water bottles. The layer, thicker in the central part of the test pit, was emplaced to protect a *cocciopesto* floor (US 7), interrupted by two ancient holes (USN 4 and USN 5) and compromised in modern times by the presence of the channel (USM 2). The excavations of the second campaign confirmed this stratigraphic situation, allowing us, however, to add some information. The east extension, despite its execution difficulties, allowed us to observe the continuation of the channel, the plastered wall and the *cocciopesto* floor which continue seamlessly in the direction of the external square.

The west extension confirmed the connection between the ancient plastered wall brought to light and the wall section that emerged in this part of the courtyard, whose apparent modernity is due to the rearrangements necessary for the construction of the current fence wall. A part of the north-south section of wall USM 3, also visible in previous photos and plans, was then unearthed for approx. 2 m. In this part of the trench, the *cocciopesto* was absent due to the emergence of the bedrock at a rather high elevation (−0.85/0.90 m approx.).

The excavation activity, contrary to initial expectations, is still ongoing. This is due to a series of unfortunate coincidences, but above all to a random event, which later proved propitious. In 2025, following an emergency intervention to repair a water pipeline, a small trench of approx. 2 × 1 m was opened in the open space in front of the gate that closes the S.I. area. The surveillance of the works revealed the archaeological interest of the area and determined the continuation of the archaeological investigation at a time and in an area not initially foreseen. The removal of the most recent use phases brought to light the continuation of the long plastered wall USM 1, never before documented in this area, and that of the *cocciopesto* floor connected to it and in excellent state of preservation.

The channel (USM 2), almost adjacent to the southern wall of the church, has an average width of approx. 0.60 m, widening towards the east. It is covered by irregularly rough-hewn lava stone slabs. The depth is on average around −1.30 m, without considering the internal fill consisting of earth and small stones filtered from above. The structure brought to light can almost certainly be connected to another similar one present close to the Via Santa Domenica street, a fact that suggests a path towards the Salto del Corvo torrent and the nearby spring area. Although its workmanship suggests a recent construction (19th century?), the excavation provided only one relative chronological datum. The channel is certainly later than the long wall USM 1, which is interrupted and damaged by the channel (Fig. 7).

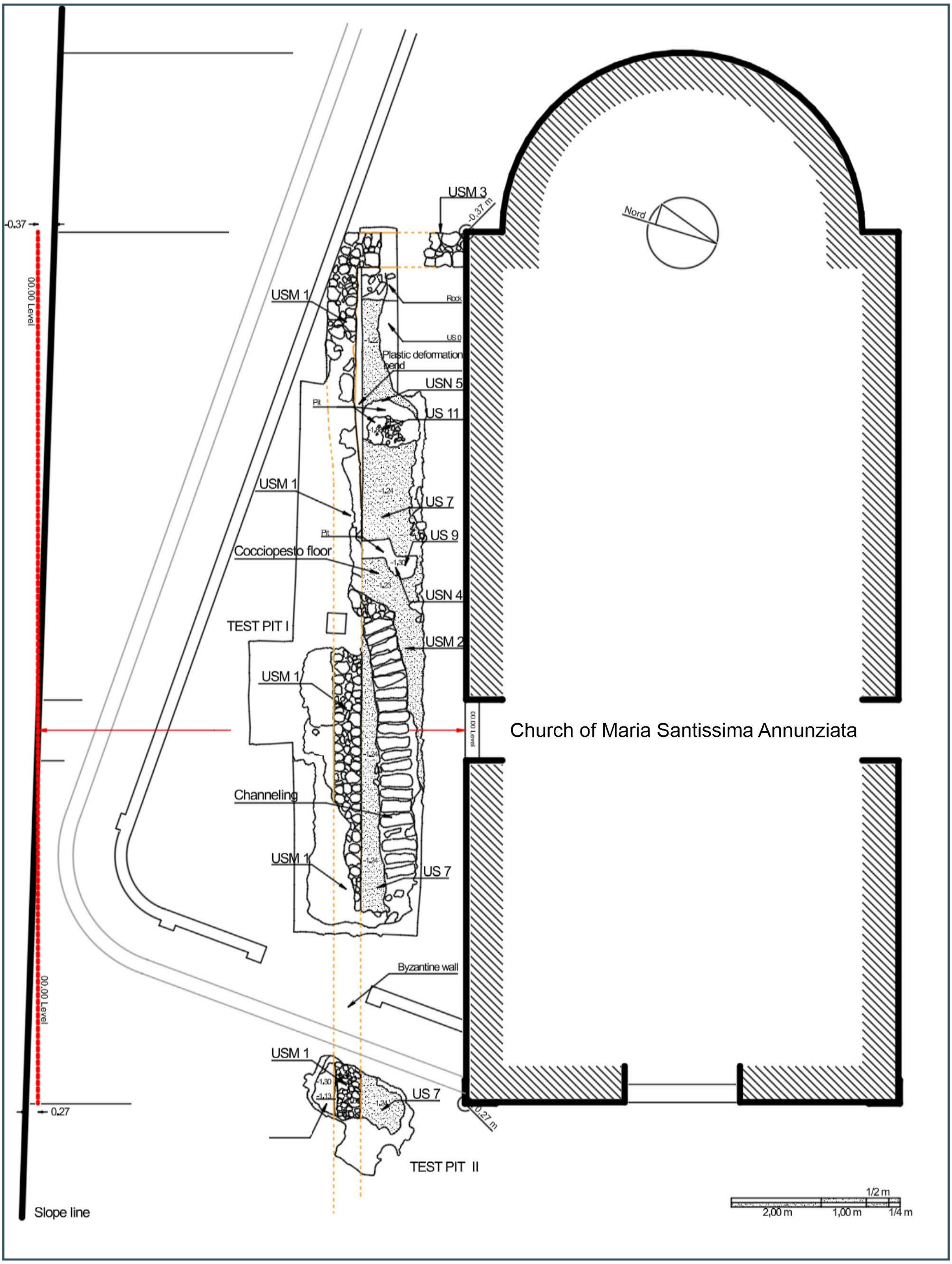

Figure 6. Plan of the archaeological excavation. The spatial continuity of the walls USM1 and USM3 are indicated by the yellow dotted line, and the *cocciopesto* floor (US7) is reported with black dots. The red line indicates the floor level.

Figure 7. Photograph of Test Pit I which highlights the channel (USM2), the plastered Byzantine wall (USM1) and the *cocciopesto* floor (US7).

A speleological exploration could be useful to acquire further data regarding its path and construction typology. The excavation therefore enabled bringing to light the southern part of a building delimited by the long east-west wall called USM 1 and by a section of the north-south wall USM 3. The first certainly coincides with the wall section marked in the 1980s planimetry and with the anomaly indicated by the investigations carried out with the georadar. Recent archaeological investigations have enabled its course to be followed for just over 19 m and, above all, to ascertain that the wall structure exits the fenced courtyard south of the church and continues to the square in front, yet without ending. No interruptions related to openings are evident. The wall, damaged and interrupted by the channel (USM 2), is made of various sized stones and lime, has a width of approx. 0.60 m and on the north side it has two layers of plaster. The oldest is light-coloured and very refined, the second, more yellowish, presents a series of more or less oblique linear incisions, but at the moment, difficult to interpret. On the other side of the wall facing the current Via Etnea street, in 2023 a small extension (Extension II) was opened which did not yield many results, because, stratigraphically, only one filling layer (US 10) again pertaining to the arrangement works of the area was intercepted. No traces of plaster were found and it was thought that it was the outer face of the wall. This hypothesis seems confirmed by test pit II of 2025 where the wall, still on the same side facing south, has a real foundation setback, probably, and no type of plaster comparable to that visible on the other face. This side could therefore be the exterior of a perimeter wall of a building whose real dimensions and, even less so, original function and possible reuses are not yet possible to appreciate. Extension II of Test Pit I, to the west, brought to light part of the north-south wall, already revealed in the 1980s (USM 3). In its lower part, untouched by the works carried out for the modern fence, it substantially presents the same characteristics as USM1, both from a structural and dimensional point of view, although the plaster seems to be almost regularly missing in the lower part. The emergence of the bedrock is then recorded in this sector of the building, against which the *cocciopesto* floor stops. This raises perplexities and, combined with the absence of plaster in the lower portion of the wall, may suggest that this area was not walkable due to the presence of an element leaning against the wall. Unfortunately, there are no certain indications in this regard. Both walls are connected to a massive *cocciopesto* floor level (US 7) 8/10 cm thick, made with mortar, stone fragments and terracotta. We believe that it can be connected to that previously documented inside and outside the current church by Taormina (2015), which was covered by a roof collapse layer characterized by combed and vacuolated tiles datable between the 6th and 8th centuries A.D. We therefore consider correct the hypothesis of a building originally wider and longer than the current one and delimited by the two parallel walls of rubble and lime, visible in the external area north (USM 1) and south of the building, at approx. 1.60 m from the presbytery enclosures. The careful cleaning of the *cocciopesto* brought to light two pits that provided us with some useful stratigraphic elements. The first pit, with a north-south orientation (USN 4), was approx. 1.35 m long, with the first section rather regular and approx. 0.30 m wide, with the fill (US 9) consisting only of stones; the more irregular section, max. 0.40 m wide, was instead very abundant in bones, whose cataloguing has not yet begun, tiles mainly of the combed type and fragments of ancient broken vessels with a corrugated surface. The fill, based on the available elements, has been dated to the 8th/9th century A.D., despite containing some tiny and absolutely residual fragments of African Sigillata D. The material ran out at approx. –1.30/–1.40 m, the depth at which we stopped. Based on the material found, the fill of the larger pit (USN 5), whose northern margin has not yet been found, had the same chronological range. The part closer to the ancient wall USM 1 had a layer of small stones, while the remaining part of the fill, indicated as US 11, returned combed tiles, parts of *cocciopesto*, plaster, and the upper part of a small lamp. The genesis of these pits remains to be clarified, also awaiting the study of all the material, including organic finds. However, they refer to a phase of abandonment of the building, since they contain elements related to the disintegration of the roof and wall structures, whose construction we must place in an era certainly prior to the 8th/9th century A.D.

Among the recovered finds, still undergoing restoration and cataloguing, are abundant early medieval tiles, already extensively documented by the 2012 excavation (Taormina, 2015). Most of them are combed and have a wide variety of decorations including wavy or curvilinear motifs impressed with fingertips, decorations with more or less deep and dense incisions with longitudinal orientation or with a net or mat decorative motif. In some cases, digital decoration is associated with incised decoration (Fig. 8a). Fragments of Roman strip tiles are also present. The pits have yielded a small slipper-type lamp (Fig. 8b), corrugated-walled pottery and the upper part of a small amphora with a typical grooved handle (Fig. 8c). Also noted is a small lithic object, approximately parallelepiped in shape with rounded corners and a large through hole. The find, of difficult typological and chronological interpretation, is still under study.

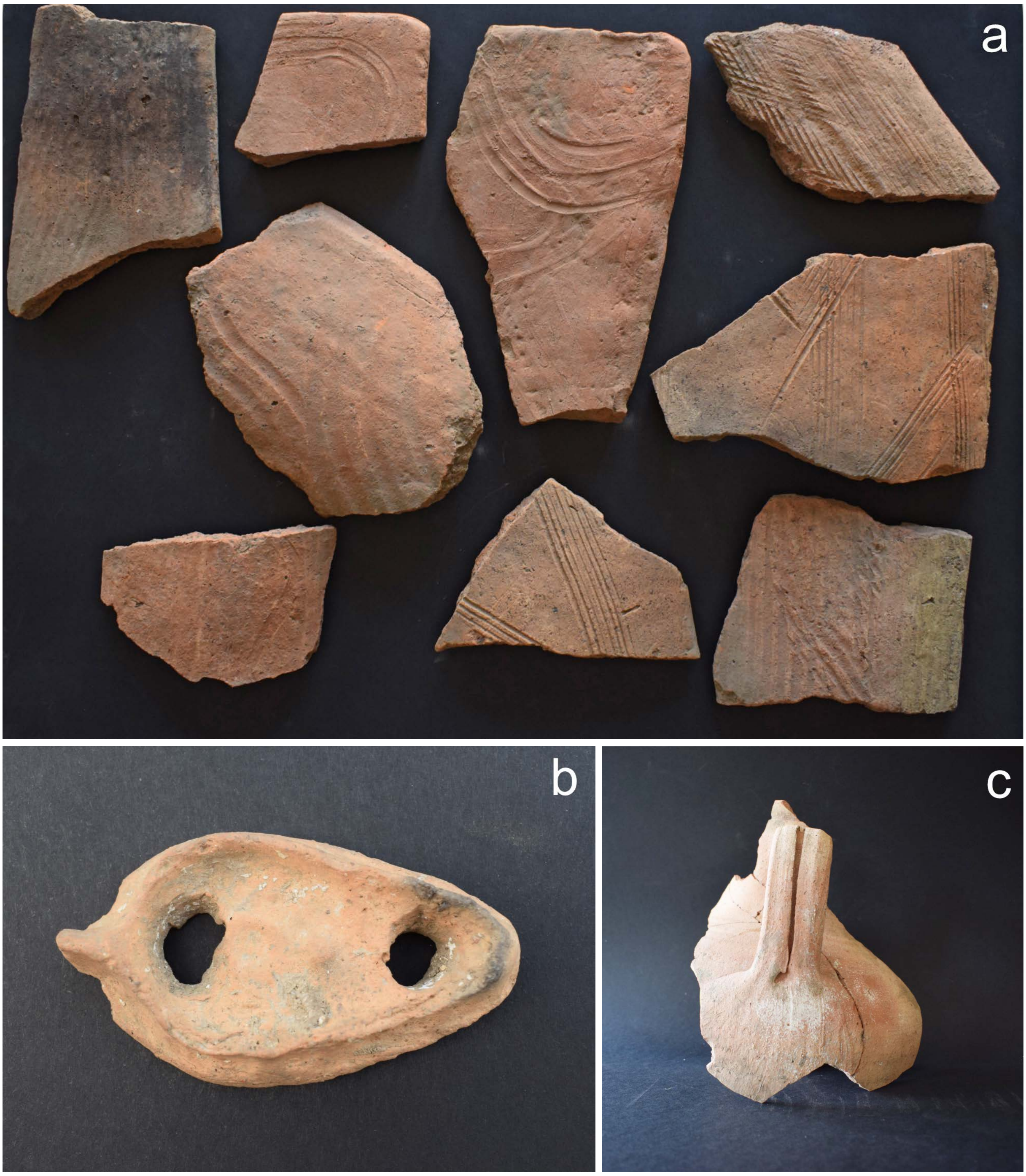

Figure 8. (a) Fragments of Byzantine-era tiles; (b) Byzantine-era lamp; (c) portion of a small fluted amphora from the Byzantine era.

4.2 C^{14} Dating

In the open space in front of the church of Maria Santissima Annunziata, a portion of a sepulchral area was discovered at a depth between −0.85 and −0.95 meters from the road level, where two skeletons were brought to light. One appeared heavily damaged by the presence of a rainwater drainage pipe, and only the lower part of the body, consisting of the pelvis and femurs, remained in situ. The second skeleton was intact and had its arms crossed on its chest (Fig. 9).

Both were laid on the bare earth, were without grave goods, and lacked any trace of a tomb structure or covering. During the excavation activities, no materials useful for establishing the chronology of the burials

Figure 9. The skeleton (IND1) of the medieval burial located close to the main façade of the church of Maria Santissima Annunziata.

Table 1. Accelerator Mass Spectrometry (AMS) radiocarbon dating performed by Beta Analytic Inc. (Miami, Florida).

Location Elevation (a.s.l.)	Sample Lab. Number	Material Method	Conventional ^{14}C age (yrs BP)	IRMSδ13C (%)	2 Sigma Calibrated age (yrs AD)	2 Sigma Calibrated age (yrs BP)
37°45′87″N 15°10′48″E 223 m	IND1 Beta-664956	Bone AMS	640 ± 30	−18.4‰	1336-1396 1285-1329	614-554 665-621
37°45′87″N 15°10′48″E 223 m	IND2 Beta-664957	Bone AMS	660 ± 30	−18.5‰	1268-1325 1352-1394	672-625 598-556
37°45′52″N 15°09′77″E 223 m	NUNZIA02 Beta-693820	Bone AMS	1270 ± 30	−17.8‰	663-775	1287-1175

were found, with the exception of a small medal, probably referable to the first individual, and a few ceramic fragments datable to the 13th century, in relation to the second individual. Carbon-14 analyses performed on the two skeletons (Table 1) confirmed this dating, placing the first skeleton between 1285 and 1396 A.D. (IND1) and the second between 1278 and 1394 A.D. (IND2). Finally, during the excavation of the USN 4 pit (Fig. 6) several fragments of animal bones were found together with fragments of Byzantine-era pottery. The C^{14} age of a bone is dated between 663 and 775 A.D. (NUNZIA02), thus confirming the proposed chronology of the pit.

5. Conclusive remarks

Etna territory is characterised by the presence of numerous archaeological sites that represent the development of human activity and the urbanization along the lower flanks of the volcano since the Greek colonization of Sicily in 735/734 B.C. In this context, the archaeological site known as Nunziatella of Mascali is located in the lower east flank of Etna at 230 m altitude in a sector of the volcano characterised by the presence of a thin cover of lava flows resting on the clays of the sedimentary basement, thereby conditioning the hydrogeological setting. Indeed, several small springs fed a narrow drainage network that over time favoured the human presence in this area that is characterised by the mediaeval church of Maria Santissima Annunziata of the XII century A.D. and by a small Paleo-Christian basilica dated about V-VI century A.D. In the past, several clues have been found in this area of the possible presence of other buried buildings. Therefore, in order to better investigate this important archaeological site of Etna region, an interdisciplinary study was performed through new geophysical investigations, archaeological excavations and C^{14} dating. The main results of this work may be summarised in the following two points.

- The results obtained from the GPR investigations highlighted how non-invasive geophysical techniques represent a fundamental support in planning archaeological excavations. The acquisition and analysis of radar data enabled the identification of a main elongated anomaly, characterized by a well-defined geometry, immediately southward of the Church of Maria Santissima Annunziata. The integrated interpretation of 2D sections and 3D time slices prompted the hypothesis of major buried structures within a depth range of approximately 0.5 m to 2 m below the ground surface. In most archaeological GPR applications, data interpretation is affected by a degree of uncertainty. In particular, the conversion from two-way travel time to depth is based on an assumed electromagnetic wave velocity, which may locally vary due to changes in soil composition, compaction, and moisture content. In addition, GPR signal amplitudes are sensitive to subsurface heterogeneity and water saturation, which can influence the detectability and contrast of buried archaeological features (Conyers, 2023; Trinks et al., 2018). Nevertheless, the coherence of the anomalies detected across adjacent B-scan profiles and time-slices, together with their spatial consistency, supports the reliability of the proposed interpretation. The results proved valuable in leading and orienting the archaeological excavations, and they, in turn, made it possible not only to verify the nature of the detected anomalies, but also to contextualize them chronologically and functionally.
- The archaeological excavation campaigns have confirmed the existence of a portion of a building on the south side of the Church of Maria Santissima Annunziata extending beyond its main facade (Fig. 10). In fact, the excavations have brought to light a section of a wall developed parallel to the southern facade of the church for over nine metres. The wall has a thick layer of plaster on the internal facade and a *cocciopesto* floor at the base that was also intercepted inside the church. This latter evidence enables deducing that the church occupied a part of the original building that was much larger and longer than the current one. Furthermore, the ages provided by C^{14} analyses, combined with the stratigraphic data from pits USN 5 and USN 4 and from the small Test Pit II, suggest that such a building was older than the 8th century. The building went out of use quite early as indicated by the presence of the two pits dated to the 8th century A.D. and referable to the frequentation of an area that changed its function. This evidence coincides perfectly with what was observed for the Paleo-Christian basilica where the first collapse of the roof and walls is dated between the end of the 7th and 8th century A.D., and attributed to a seismic event not identifiable or to a degradation of the already abandoned site. All these new archaeological data allow us to hypothesize the presence of a large building from the Byzantine era of unknown function whose extension towards the east and north is not yet known and therefore the spatial and temporal relations with the probable contemporary Paleo-Christian Basilica are still to be defined.

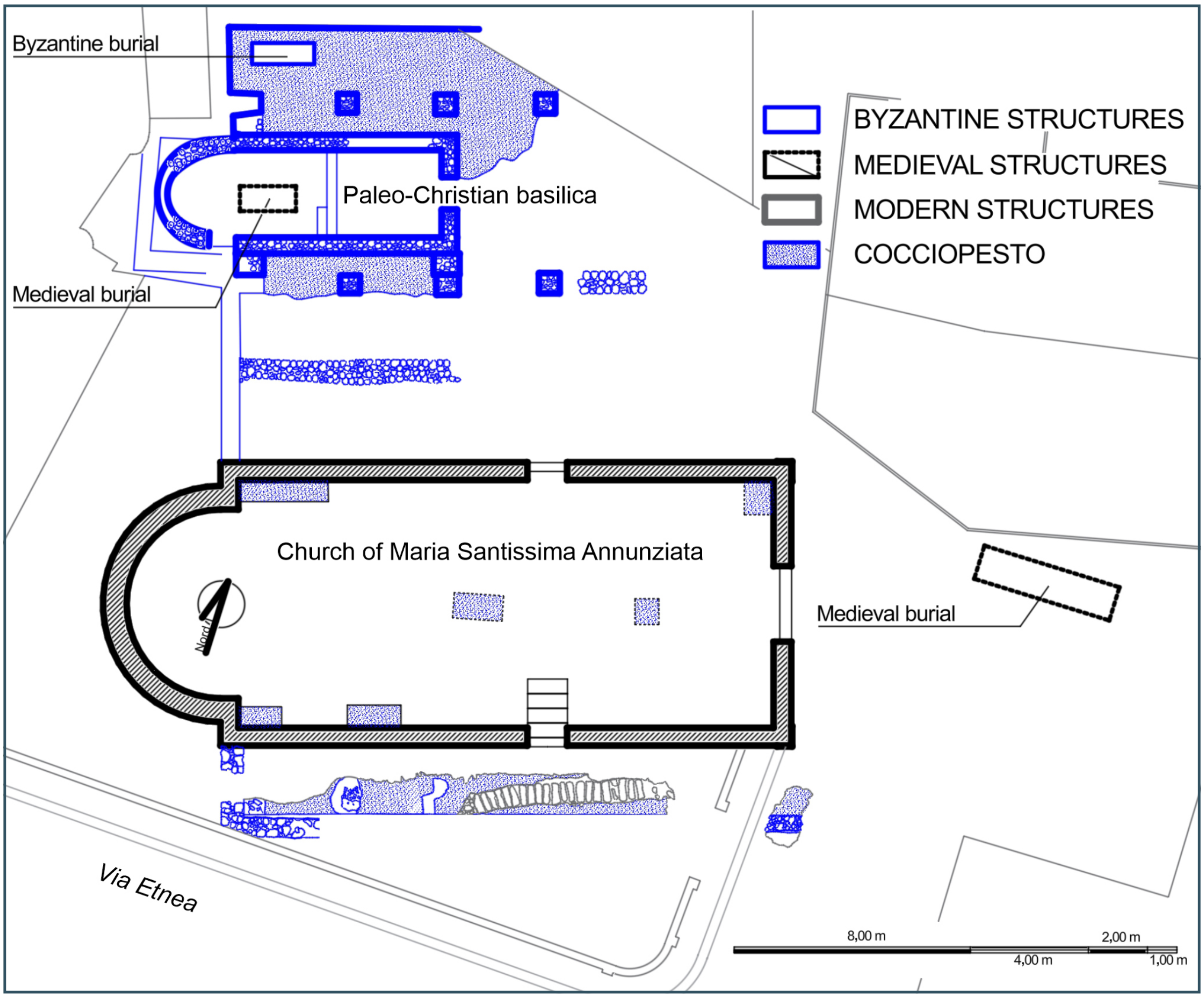

Figure 10. Plan of the archaeological site of Nunziatella in Mascali with the various archaeological finds.

In conclusion, the archaeological excavation has provided some particularly relevant data, even if further geophysical and archaeological investigations are necessary. It has highlighted the historical importance of the monumental complex of the Nunziatella of Mascali, testifying to an uninterrupted attendance since ancient times of this area of Etna volcano, rich in water sources and therefore suitable for human settlement.

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References

AA.VV. (2012). Città di Mascali, Quaderno di studi N. 2, 224 p., Riposto.
AA.VV. (2020). Etna 1928-2018, A 90 anni dall'eruzione e dalla ricostruzione di Mascali, Riposto.
AA.VV. (2024). Dai monasteri e dai conventi: Tesori d'arte: Catania, Museo Diocesiano, Regione Sicicliana.
Annan, A. P. and S. W. Cosway (1994). GPR frequency selection, in Proceeding of the Fifth International Conference on Ground Penetrating Radar (GPR '94), June 12-16, Kitchener, Ontario, Canada, 747-760.

Basile, V., M. T. Carrozzo, S. Negri, L. Nuzzo et al. (2000). A ground penetrating radar survey for archaeological investigations in an urban area Lecce (Italy), J. Appl. Geophys., 44, 15-32.

Branca, S., M. Coltelli, G. Groppelli and F. Lentini (2011a). Geological map of Etna volcano, 1:50,000 scale, Ital. J. Geosci., 130, 3, 265-291, doi:10.3301/IJG.2011.15.

Branca, S., M. Coltelli and G. Groppelli (2011b). Geological evolution of a complex basaltic stratovolcano: Mount Etna, Italy., Ital. J. Geosci., 130, 3, 306-317, doi:10.3301/IJG.2011.13.

Branca, S. and V. Ferrara (2013). The morphostructural setting of Mount Etna sedimentary basement (Italy): implications for the geometry and volume of the volcano edifice and its flank instability, Tectonophysics, 586, 46-64. doi:10.1016/j.tecto.2012.11.011.

Branca. S. and V. Ferrara (2001). An example of river pattern evolution produced during the lateral growth of a central polygenic volcano: the case of the Alcantara river system, Mt. Etna (Italy), Catena, 45/2, 85-102.

Buda, G. (a cura di) (2015). La Nunziatella sopra Mascali, Palermo.

Buda, G. (2015). Scoperte e restauri alla Nunziatella tra il 2012 e il 2013 in Buda G., (a cura di), La Nunziatella sopra Mascali, Palermo, 19-67.

Calì, A., S. Raccuglia (1901). Storia delle città di Sicilia – Mascali, Acireale.

Campo, G. (2024). Dalla Legazia apostolica (1098) alla Legge delle Guarentigie (1871), in AA.VV., Dai monasteri e dai conventi: Tesori d’arte: Catania, Palermo, pp. 82-87.

Conyers, L. B. and D. Goodman (1997). Ground Penetrat¬ing Radar. An introduction for archaeologists, 232 p., AltaMira Press, Walnut Creek, California.

Conyers, L. B. (2015). Analysis and interpretation of GPR datasets for integrated archaeological mapping, Near Surf. Geophys. 13, 645-651, doi:10.3997/1873-0604.2015018.

Conyers, L. B. (2023). Ground-penetrating radar for archaeology. Lanham, MD: Rowman and Littlefield Publishers. ISBN: 978-1538179352.

De Beni, E., S. Branca, M. Coltelli, G. Groppelli and J. Wijbrans (2011). 39Ar/40Ar isotopic dating of Etna volcanic succession. Ital. J. Geosci., 130, 3, 292-305, doi:10.3301/IJG.2011.14.

Di Mauro, L. (2009). Affreschi bizantini nella contea di Mascali in Kronos, Lecce.

Goodman, D. and S. Piro (2013). GPR Remote Sensing in Archaeology. Geotechnologies and the Environment Series, vol. 9, Springer-Verlag, Berlin.

Goodman, D., Y. Nishimura and J. D. Rogers (1995). GPR Time Slices in Archeological Prospection, Archeological Prospection, 2, 85-89.

Indelicato, M. (2019). Contributo per una carta archeologica della “Contea di Mascali” in Cronache di Archeologia, Catania.

Lanzafame G., M. Neri, M. Coltelli, L. Lodato and D. Rust (1997). Compressione Nord-Sud nella regione del Monte Etna (Sicilia): distribuzione spaziale e temporale, Acta Vulcanol., 9, 121-133.

Lentini, M. C. (1982) Nunziata (Catania): area cimiteriale di epoca bizantina (VI-VII secolo) in BCASic 3, Palermo, 177-180.

Maganuco, E. (1939). Cicli di affreschi medievali a Randazzo e a Nunziata di Giarre, Catania.

Marano, G. (2015). I precedenti interventi della Soprintendenza alla Nunziatella in Buda G., (a cura di), La Nunziatella sopra Mascali, Palermo, 13-17.

Orsi, P. (1930). Sicilia. Annunziata di Mascali, in BCom, Roma 1930, p. 143.

Privitera, F. (2015). Frammenti preistorici dallo scavo dell’abside della basilichetta in Buda G., (a cura di), La Nunziatella sopra Mascali, Palermo, 126-137.

Privitera, F. and M. R. Grasso (2012). Il territorio di Mascali e l’archeologia, in AA.VV., Città di Mascali, Quaderno di studi, Riposto, 85-96.

Taormina, A. (2015). Le indagini archeologiche e i materiali in Buda G., (a cura di), La Nunziatella sopra Mascali, Palermo, 98-123.

Trinks, I., A. Hinterleitner, W. Neubauer, E. Nau, et al. (2018). Large-scale high-resolution ground-penetrating radar measurements for archaeological prospection, Archaeol. Prosp., 25, 3, 171-195, doi:10.1002/arp.1599.

***CORRESPONDING AUTHOR: Stefano BRANCA**,

Istituto Nazionale di Geofisica e Vulcanologia – Osservatorio Etneo, Catania, Italy

e-mail: stefano.branca@ingv.it