2025 IMEKO TC26 International Conference on
Metrology for Archaeology and Cultural Heritage
Bergamo, Italy, October 15-17, 2025

An integrated approach to the study of the architectural features of the theatre of Tyndaris

Marco Sfacteria[1], Stefania Tuccinardi[2], Marta Venuti[3]

[1] *University of Messina, Department of Ancient and Modern civilization, marco.sfacteria@unime.it*
[2] *University of Messina, Department of Ancient and Modern civilization, stefania.tuccinardi@unime.it*
[3] *University of Messina, Department of Ancient and Modern civilization, marta.venuti@unime.it*

***Abstract* – The ancient theatre of Tindari, located in the southeastern sector of the ancient city, is adapted to a particularly narrow and steep hillside morphology, which necessitated hybrid construction solutions. This study aims to clarify the construction techniques, structural adaptations, and subsequent transformations of the *koilon*, addressing the gap in understanding the functional and structural role of the theatre's earth-retaining and annular corridor. To achieve this, archaeometric analyses of mortars are combined with geomorphological assessment. The *cavea*, partially carved into the natural rock, is completed by artificial earth fill supported by massive analemma walls, particularly at the outermost sections. The discontinuity of the bedrock and the transverse structural thrusts have caused deterioration phenomena and localized collapses since antiquity. The study demonstrates that the annular corridor and *podium*, previously interpreted primarily in functional terms, played a decisive structural role. These findings provide a basis for informed conservation strategies and highlight the original contribution of this research in reevaluating the theatre's construction logic and structural behavior.**

I. INTRODUCTION

The Work Package 6 (WP6) of the Samothrace project aims to develop an integrated system for monitoring the conservation status of ancient buildings, combining traditional archaeological research methods with advanced techniques from chemistry, physics, and sensor engineering [1, 2]. This paper focuses on the theatre of Tindari, one of the case studies examined within the project, with the aim of reconstructing the conditions that, in antiquity, necessitated structural interventions on the monument, as well as the technical solutions that were adopted. Particular attention is given to the analysis of construction dynamics and the functional transformations of the *koilon*, with the goal of understanding the strategies employed in different historical periods to contain the embankment, and thereby to propose informed conservation approaches grounded in a thorough knowledge of the site.

In addition to deterioration caused by atmospheric agents and, more generally, by environmental factors and the stresses associated with the use of the monument, a further critical issue is its structural vulnerability, due to the geophysical and geodynamic characteristics of the area where the theatre is located.

Understanding these phenomena requires a re-examination of the monument's various construction phases. A detailed analysis makes it possible to link specific architectural solutions and ancient restoration interventions to the geological features of the context. This study adopts an integrated approach, combining a physicochemical analysis of mortars—used in both ancient and modern phases of construction and restoration—with a broader geomorphological and structural assessment. Comparing these datasets allows for a clearer understanding of the technological and architectural choices made over time.

Such knowledge is essential for defining new and effective strategies for the conservation and protection of the theatre.

II. GEOLOGICAL AND GEOMORPHOLOGICAL FRAMEWORK

The promontory of *Capo Tindari*, located on the Tyrrhenian margin of the *Peloritani* mountain range, on the northeastern coast of Sicily in the province of Messina, is composed of a complex of stacked tectonic units with southward vergence that began to accumulate during the Oligocene. These units include a crystalline Hercynian basement overlain by Meso-Cenozoic sedimentary deposits [3]. Resting unconformably on this entire complex is the Capo d'Orlando Flysch, a terrigenous formation dated to the Lower Oligocene–Miocene.

Its steep rocky cliff, which reaches a height of 292.7 meters above sea level, is composed predominantly of lithotypes belonging to the Aspromonte Unit, which are intensely tectonized and consist of pre-Mesozoic metamorphic rocks and medium-grained light gray marble beds [4].

The entire area is affected by significant tectonic instability, mainly associated with the so-called "Tindari Fault" system—a NNW-trending structure connecting the central Aeolian Islands with the Ionian coast of northeastern Sicily. This fault has caused documented right-lateral strike-slip and extensional movements, particularly during the Middle to Upper Pleistocene [5, 6].

This fault system intersects other NE–SW striking faults, generating a complex tectonic mosaic that has contributed to the uplift and displacement of the metamorphic basement, thus forming the steep cliffs that today characterize the promontory [7].

At the base of the Capo Tindari cliff extends the Marinello lagoon system—a dynamic and ever-changing environment composed of coastal bars, sandy spits, dunes, and coastal lagoons.

The coastal plain to the east of the Tindari promontory is a relatively recent Holocene formation. The genesis of the sandy bank at the base of the promontory can be attributed to a combination of both natural and anthropogenic factors. From a natural perspective, the past four centuries have seen intense depositional activity driven by the combined action of marine and fluvial processes—particularly by the Timeto and Elicona rivers, which transported sediments from the Nebrodi reliefs and caused progressive aggradation of the plain [8].

These materials, transported and redistributed by longshore currents, gradually formed spits that curved toward the coast and progressively isolated bodies of water, thereby giving rise to the current coastal lagoons. In particular, the energy of the currents decreases sharply along the eastern stretch of the promontory, near the locality of Mongiove, encouraging the deposition of large volumes of sediment and the formation of the sandy bank [9].

The collapse of a portion of the Tindari cliff, already documented in Roman times by Pliny the Elder—who wrote that "the sea took from Sicily half of the city of Tyndaris" (*Naturalis Historia*, II, 206)—likely contributed to modifying the bathymetry of the seabed, thus creating favorable conditions for sediment accumulation. This catastrophic event may have been triggered by an earthquake, marine erosion, or a combination of both [9].

Over the centuries, numerous landslides and rockfalls have been recorded, supported by both historical accounts and modern monitoring data. The entire area of the promontory is currently classified as a high geomorphological risk zone in the Hydrogeological Risk Management Plan (PAI) of the Sicilian Region [8].

Finally, human activity has played a fundamental role in the geomorphological evolution of the area. The centuries-long deforestation of the Peloritani slopes, documented as early as the 15th century, intensified erosive processes by increasing the sediment load carried by streams to the coast [10]. Moreover, the construction of ports and infrastructure along the coast has altered littoral currents, promoting sedimentation in some areas and erosion in others.

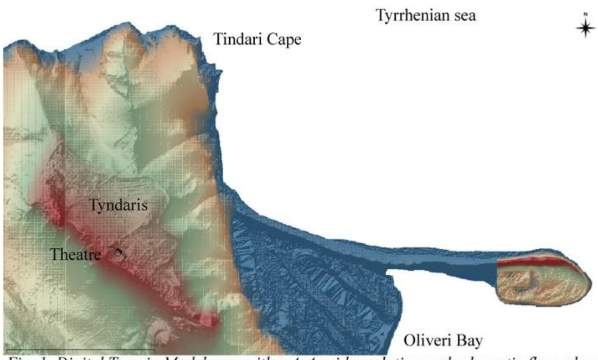

Fig. 1. Digital Terrain Model map with a 4x4 grid resolution and schematic floor plan of the Theatre. Reprocessed picture from National Geoportal data.

III. THE THEATRE: ARCHITECTURAL AND STRUCTURAL FEATURES

The theatre of Tindari is located in the south-eastern sector of the ancient city, on the eastern slope of the southernmost tip of the Capo Tindari hill. The ridge, fortified since the Hellenistic period, extends in a north-west/south-east direction for about one kilometre and features a narrow and elongated morphology. At the point where the theatre stands, the ridge reaches a maximum width of about 30 metres, with an elevation difference of 10 metres across a comparable transverse span. This orographic configuration made it impossible to excavate the entire *koilon* directly into the bedrock, requiring the adoption of mixed construction solutions.

Fig. 2. ortophoto of the theatre

A. Cavea construction techniques

The central part of the *cavea* was carved directly into the natural rock, while the northern and southern ends were built on massive artificial embankments. On the eastern side, which is particularly steep, these substructures were supported by substantial *analemma* walls. The discontinuity of the geological substrate on which the *cavea* rests, combined with the structural forces directed from west to east, contributed to progressive degradation phenomena since antiquity, including partial collapses and subsequent consolidation interventions. In addition, the city was affected by seismic shifts at various historical moments, as confirmed by the archaeological evidence.

The theatre occupies a surface area of approximately 4,500 m², bounded to the west by the *decumanus* and to the east by the eastern slopes of the ridge. The geometric configuration of the building integrates harmoniously into the urban layout of the ancient city: its western side faces the *decumanus*, which narrows in correspondence with the stage building to accommodate its footprint. Transversely, the monument spans approximately three urban blocks.

As noted, the *cavea* is partially excavated into the bedrock; its ends, however, were constructed on artificial embankments contained by two monumental *analemma* walls made of local sandstone blocks, the same type used in the city walls.

The configuration of the *cavea* remains one of the most debated aspects among scholars [11, 12]. The most widely accepted reconstructions suggest the presence of eleven wedges (*kerkídes*) consisting of at least twenty-eight rows of seats, separated by ten radial staircases [13, 14]. However, this traditional division into eleven *kerkídes* raises certain issues, such as the lack of consideration for possible *vomitoria* within the *analemma* walls, as observed in other Sicilian and Mediterranean theatre contexts.

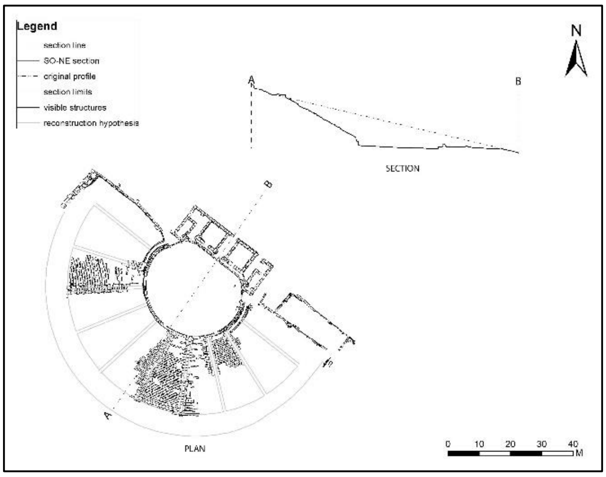

Fig. 3. Plan and section of the theatre

B. Roman modifications

During the Roman period, the theatre underwent significant transformations, including the removal of the lower steps of the *cavea* to enlarge the diameter of the orchestra for performances involving wild animals. This intervention altered the static balance of the building, especially in the areas built on embankment, where lateral thrusts became more concentrated.

Concurrently with this transformation, an annular corridor was built around the orchestra, serving both as a protective barrier for the audience and as lateral support for the embankment. The site's varying geotechnical characteristics are reflected in the structural heterogeneity of this corridor. At the ends of the *cavea*, the corridor is a through-passage, built by placing a retaining wall opposite, on the inner side, a low wall or *podium*, made of reused materials. The corridor was covered by a barrel vault in *opus caementicium* and finished, on the side facing the orchestra, with a moulded limestone cornice. In contrast, in the central part of the *cavea* – excavated directly into the rock – only the *podium* wall was constructed, serving to mask the rock cut but without structural function.

C. Restoration phases

On-site analysis of the masonry has revealed numerous restoration interventions of varying scale and systematicity. The study currently underway aims to clarify these phases, including their chronology. To obtain a comprehensive picture, archaeometric analyses are being employed to correlate structural data with material evidence and to define the sequence of interventions with greater precision. On-site analysis of the masonry has allowed the identification of five distinct construction phases:

- Phase I is primarily recognized in the *koilon* and involved the initial division into wedges and the construction of the supporting embankments, delimited at the ends by two double-faced analemma walls executed in finely dressed isodomic masonry, with a thickness of approximately 2 m.
- Phase II is represented by a wall built to consolidate for the first time the eastern extremity of the *koilon*.
- Phase III includes a significant number of structures built both in *opus caementicium* and by reusing squared blocks from the first phase, aimed at a structural consolidation of the entire *koilon*. Some evidence suggests that the eastern analemma wall may have collapsed or been systematically dismantled and rebuilt following internal consolidation of the embankment.
- Phase IV coincides with the transformation of the theatre in order to host *venationes.* In this moment the annular corridor was built.
- Phase V consists of the reconstruction of the *podium* wall.

After this phase, no further restoration interventions are documented, suggesting that the theatre was eventually decommissioned.

Analyzing these transformations highlights how the issue of structural instability in the *koilon* shaped the monument's entire history, from its initial construction through all subsequent modifications and restorations.

IV. CONCLUSIONS

The exceptional geological complexity of the Capo Tindari promontory, combined with the site's seismic vulnerability and irregular morphology, has profoundly influenced the theatre's construction history and functional transformations. From the earliest phase, the irregularities of the terrain and the uneven substrate required innovative technical solutions to ensure stability, particularly in the *cavea* and its supporting embankments.

Until now, no systematic study had focused on the theatre's technical and structural aspects or on the detailed sequence of its construction and consolidation phases. Earlier research largely emphasized typological or architectural interpretations, often overlooking the engineering challenges posed by the site's geology and the persistent issue of structural instability.

Our comprehensive analysis of construction techniques, building materials, and the five identified phases reveals that the *cavea*'s stability was a recurring concern throughout the theatre's history. Phase I shows the careful establishment of the wedge system and the supporting embankments bounded by double-faced analemma walls. Subsequent phases document repeated consolidation efforts, including the partial reconstruction of the eastern analemma wall and the reinforcement of the embankment with both reused blocks and *opus caementicium* masonry. The construction of the annular corridor in Phase IV emerges not merely as a functional adaptation for performances but as an essential structural solution, distributing lateral thrusts and ensuring the long-term stability of the *cavea*. Even later modifications, such as the *podium* wall reconstruction in Phase V, were directly related to the ongoing challenge of maintaining structural integrity.

By analyzing these transformations in detail, it becomes clear that the theme of structural instability governed the theatre's entire life from its initial construction onward. This study, grounded in archaeometric analyses of mortars and meticulous architectural documentation, represents a crucial original contribution: it demonstrates how technical solutions were devised and adapted over time to respond to the site's geological and seismic constraints.

These results not only refine our understanding of the theatre's construction history and the technological rationale behind past interventions but also provide a solid framework for current and future conservation strategies. Such strategies are presently being implemented and tested within WP6 of the Samothrace project, ensuring that the lessons derived from centuries of construction, transformation, and adaptation can directly inform its preservation.

V. ACKNOWLEDGEMENTS

This research activity was funded by the European Union (NextGeneration EU), through the MUR-PNRR project SAMOTHRACE (ECS00000022) "SiciliAn MicronanOTecH Research And Innovation CEnter"– Ecosistema dell'innovazione (PNRR, Mission 4, Component 2 Investment 1.5, Avviso n. 3277 del 30-12-2021), Spoke 2 – University of Messina – Work Package 6 Cultural Heritage.

REFERENCES

[1] G.Paladini, F.Caridi, D.Majolino, M.Sfacteria, S.Tuccinardi, M.Venuti, G.Lando, P.Cardiano, V.Venuti, "Multi-technique diagnostic analysis of natural and artificial lithic fragments from the theatre of the archaeological area of Tindari (Sicily, Southern Italy)", Proceedings of the Metroarchaeo 2024, in press.

[2] M.Sfacteria, M.Venuti, S.Tuccinardi, "New investigations at the Theatre of Tindari: Samothrace Project, methods and preliminary results", Proceedings of the Metroarchaeo 2024, in press.

[3] F.Lentini, L.Vezzani "Le unità meso-cenozoiche della copertura sedimentaria del basamento cristallino peloritano (Sicilia nordorientale)", Bollettino della Società Geologica Italiana, No.19, 3, 1975, pp. 537-554

[4] F. Lentini, S.Catalano, S.Carbone, "Carta geologica della provincia di Messina: scala 1:50.000 e nota illustrativa", Firenze: S.E.L.C.A. 2000

[5] G.De Astis, G.Ventura, G.Vilardo, 2003, "Geodynamic significance of the Aeolian volcanism (Southern Tyrrhenian Sea, Italy) in light of structural, seismological and geochemical data", Tectonics No.22 (4), 2003, pp. 1040–57.

[6] F.Cultrera, G.Barreca, L.Ferranti, C.Monaco, F.Pepe, S.Passaro, G.Barberi, V.Bruno, P.Burrato, M.Mattia, C.Musumeci, L.Scarfì, "Structural architecture and active deformation pattern in the northern sector of the Aeolian-Tindari-Letojanni fault system (SE Tyrrhenian Sea–NE Sicily) from integrated analysis of field, marine geophysical, seismological and geodetic data", Italian Journal of Geosciences, No.136, 2017, pp. 108-112.

[7] A.Billi, G.Barberi, C.Faccenna, G.Neri, F.Pepe, F.Sulli, "Tectonics and seismicity of the Tindari Fault System, southern Italy: Crustal deformations at the transition between ongoing contractional and extensional domains located above the edge of a subducting slab", Tectonics, No. 25, 2006, pp. 1-20.

[8] C.Bottari, M.D'Amico, M.Maugeri, A.Bottari, G.D'Addezio, B.Privitera, G.Tigano, "Location of the ancient Tindari harbour from geoarchaeological investigations (NE Sicily)", Environmental Archaeology, No.14 (1), 2009, pp. 37–49.

[9] S.Privitera, S.Torre, "Le lagune di Oliveri-Tindari: un

caso di interazione tra azione antropica ed evoluzione ambientale”, Annali della Facoltà di Scienze della Formazione Università degli Studi di Catania, No.6, 2009, pp. 111-157.

[10] P.Mazzeo, “La dinamica delle aree boschive in Sicilia attraverso la cartografia”, in C.Polto (Ed.), “La cartografia come strumento di conoscenza e di gestione del territorio”, atti del Convegno di Studi, Messina, 29-30 marzo 2006, Messina, 2006, pp. 403-411.

[11] H.Bulle, W.Wrede, K.Lehmann, H.Wirsing, H. Möbius, “Untersuchungen an griechischen Theatern”, München 1928, 131-152, tavv. 33-41.

[12] L.Bernabò Brea, “Due secoli di studi, scavi e restauri del teatro greco di Tindari”, Rivista dell'Istituto nazionale d'archeologia e storia dell'arte, No.13/14, 1964/1965, pp. 99-144.

[13] U.Spigo, “Il teatro di Tindari. Tutela e conoscenza”, in G.Meli (ed.), “Teatri antichi nell’area del Mediterraneo. Conservazione programmata e fruizione dei contributi analitici alla carta del rischio. La materia e i segni della storia”, Atti del II Convegno Internazionale di Studi, Siracusa 2004, pp. 385-395, Regione Siciliana, Dipartimento beni culturali ed ambientali ed educazione permanente, Palermo (2007).

[14] M.Panagiotonakou, “Revisiting the Theater of Tyndaris. A New Chronology Proposal”, Journal of Ancient Architecture, No. 2, 2023, pp. 9-30.