IN SECOND USE

AN ARCHAEOLOGICAL AND ANTHROPOLOGICAL SURVEY OF RECYCLING AND REUSE IN THE GREEK WORLD

Edited by Nikolas Dimakis, Paraskevi Motsiou and Eurydice Kefalidou

AURA SUPPLEMENT 13 • ΣΕΙΡΑ ΜΟΝΟΓΡΑΦΙΩΝ AURA 13

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TRAASH

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ΣΕΙΡΑ ΜΟΝΟΓΡΑΦΙΩΝ AURA 13

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Cover Photo: Tower of the Frankish castle of Paros (modern-day Parikia), made almost exclusively of ancient marble architectural members. Photo by Alexios Govolko.

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PROOFREADING & LAYOUT • ΤΥΠΟΓΡΑΦΙΚΗ ΕΠΙΜΕΛΕΙΑ & ΣΧΕΔΙΑΣΜΟΣ

Katerina Boukala-Karkagianni

Editorial • Εκδοτικό Σημείωμα

The Athens University Review of Archaeology (AURA) is an international, peer-reviewed archaeological journal published by the Faculty of History and Archaeology of the National and Kapodistrian University of Athens. It is dedicated to the publication of original research articles and reports focusing on, or related to the archaeology, art and material culture in the broader Greek world, from the earliest Prehistory to the Modern Era.

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PROLOGUE

It gives me great pleasure to introduce this innovative volume of proceedings from the International Meeting for Early Career Scholars, "In Second Use: An Archaeological and Anthropological Survey of Recycling and Reuse in the Greek World" [held on 25–26 September 2021 (via Webex)], as part of the TRAASH project (Tracking Re-cycling: Archaeological and Anthropological Survey in the Habitat of Xanthi Region-Thrace), funded by the H.F.R.I.

This collective work reveals the sophisticated ways in which different cultural groups, throughout different historical periods, developed material practices that demonstrate remarkable understanding of resource management and reuse. The timing of this publication could not be more appropriate. As our global community faces unprecedented environmental challenges, this collection of research demonstrates how the study of past practices can illuminate paths forward.

What makes this collection particularly valuable is its temporal and methodological scope. Ranging from prehistoric settlements to modern communities, the research explores how objects, spaces and landscapes have been reimagined and repurposed across time. Whether investigating the reuse of transport amphorae in ancient architecture, studying the repurposing of statues and altars in Hellenistic and Roman sanctuaries, examining the transformation of ancient sacred spaces into residential areas, analyzing fragmented burial vessels in Minoan tombs, documenting the reuse of architectural features in Prepalatial settlements, exploring foundation deposits in Classical houses, or tracing the evolution of ancient burial grounds, these studies reveal the remarkable continuity and evolution of human approaches to material culture.

This volume brings together the groundbreaking work of an emerging generation of scholars –doctoral candidates, recent PhD recipients and postdoctoral researchers in archaeology, anthropology and related humanities disciplines– who are reshaping our understanding of historical evolution of 'waste' as a concept and demonstrating how different cultural groups have approached resource utilization across time.

May this collection serve not only as a significant contribution to archaeological scholarship, but also as an inspiration for developing sustainable solutions to our present environmental challenges. It stands out as testimony to how cultural groups developed sustainable practices long before sustainability became a global mperative, to how humanities research can contribute meaningfully to contemporary societal needs, while maintaining the highest standards of scholarly inquiry.

I would like to warmly congratulate the Editors and all the participants and wish your book a wonderful journey.

Dimitrios L. Drosos
Dean of the School of Philosophy
Professor of Spanish and Spanish-American Civilization
National and Kapodistrian University of Athens, Greece

INTRODUCTION

The present volume of the Proceedings of International Meeting for Early Career Scholars titled "In Second Use: An archaeological and anthropological survey of recycling and reuse in the Greek world" is a product of the Tracking Re-cycling: Archaeological and Anthropological Survey in the Habitat of Xanthi Region-Thrace (TRAASH) project (https://traashbaggie.gr/FreeSite/), funded by H.F.R.I., in the framework of 1st Call for H.F.R.I. Research Projects to Support Faculty Members & Researchers and Procure High-Value Research Equipment. The idea for such a research project was born out of numerous observations and many questions that arose from the research team's long-term involvement with material culture, sites and landscapes in various regions of Greece. Complementary to these, was the realization that younger generations, growing up in urban environments, are not familiar with the long-standing efforts for the 'prudent' management of the objects of everyday life, as well as of natural resources and the landscape, i.e. with many important parameters that were taken for granted in traditional forms of agro-pastoral life and pre-industrial production and economy.

All of us who study material culture, in time constantly encounter instances of reuse, recycling and redefining the use of a multitude of objects. These practices, which have been the subject of so much talk and so much awareness-raising in recent decades, were part of the everyday life, not only of the ancient Greeks, but also of traditional Greek communities. Everyone, without exception, systematically reused, modified according to their needs and/or recycled countless categories of objects: metal objects such as tools, vases, weapons or coins were melted down to make new objects with the same or a different use (recycling), while metal jewelry sheets were cut to make smaller artifacts (modification and reuse). Fragments of glass objects were melted down and reproduced as glass vases and objects (recycling). Various stone sculptures and stone blocks were incorporated into fortification walls, building walls and thresholds, or processed to make basins and other everyday or special utensils (reuse). A variety of ceramic objects were also reused in numerous ways, repaired or not, intact or in fragments (even pulverized).

It is obvious that the issues our research programme studies are many, important and diachronic. A three-year research could not but focus on one main field, which in our case was the geographical one: the diachronic examination of recycling, reuse and the re-adaptation of the environment, materiality and ideas in a specific geographical unit, in the Prefecture of Xanthi, from Antiquity to the present day. Xanthi Prefecture was chosen as a case study for waste management, as it allows for a diachronic and synchronic study of these practices by various cultural groups of the past, such as the Greek settlers of Thrace and the indigenous Thracians, and later by traditional and modern agro-pastoral communities, many of which still maintain many of the 'traditional' ways of life, especially in the mountain villages of Rhodope.

An important parameter that had to be considered was the interdisciplinary nature of the research approach. Thus, a broad team of researchers of various disciplines archaeologists, anthropologists, a museum pedagogue-museum educator, but also experts in geographic information systems (GIS), an IT technician and even a visual artist, well known for his work on the recycling of materials in art (Trash-Art), was set up. Several of the research team members were already collaborating, in the framework of another intensive surface research project under the direction of the Ephorate of Antiquities of Xanthi entitled: "APAX: Archaeological Project of Abdera, Xanthi, 2015–2019', together with dozens of undergraduate and postgraduate students, as well as postdoctoral researchers from the National and Kapodistrian University of Athens. Indeed, some of

them had occasionally dealt with various aspects of the issue of reuse and recycling in antiquity. The TRAASH project has allowed us to join forces again, pooling our strengths, experience and specializations, but also to collaborate with other experts.

Through the research project, we have tried, as far as possible, to document, study, interpret and exploit to our advantage the various (continuous, evolving or changing) ways of exploiting and managing objects, landscape and natural resources, which are irrefutable evidence of how different cultural groups were active over time within the same geographical context. The perception and application of secondary use also involves symbolic meaning with strong cultural implications. A diachronic analysis of these parameters can contribute to the creation of a model of environmental and material sustainability, which could be applied to today's societies.

A major difficulty that arose right from the start was the Covid-19 epidemic, which did not allow us to visit the region at all in 2020 –I recall that Xanthi Prefecture was one of the areas with the highest epidemiological burden during the first phase of the pandemic's spread and our project had a start date of 18/12/2019. In addition, the closure of scientific libraries due to sanitary conditions during March – August 2020, and the limited access to them during 2021, affected the productivity of researchers, as their ability to draw on the information was limited (the available electronic resources did not significantly contribute to facilitate their research). Thus, some necessary changes had to be made from the original project design, especially in the fieldwork components of the research that concerned specific villages in Rhodope. These gaps were filled as far as possible and thus the results of the project were not significantly affected.

Eurydice Kefalidou

The international meeting "In Second Use: An archaeological and anthropological survey of recycling and reuse in the Greek world" –held on 25–26 September 2021 via Webex– aimed to bring together early career scholars (PhD students, recent PhD holders and postdoctoral researchers) from various fields of the Humanities –archaeology, history, ethnoarchaeology, folklore– working on any aspect of secondary use in the Greek world from prehistory to modern times. They presented, alongside the researchers of the TRAASH project, thematic and/or interdisciplinary ways of analysis, in which evidence of secondary use, as attested in material or non-material culture, the landscape or natural resources, provides insights on individuals, social groups or communities.

The volume begins with the PI's, Eurydice Kefalidou, paper as an introduction to the concept of 'waste' through time. It also presents three examples of secondary use and reuse of pottery at ancient Abdera, which highlight the importance of studying all the cycles of use of material culture, a concept and a practice that reflects cultural behaviors and brings to light important aspects of economy, personal and collective identity, ideology, memory and worship – subjects directly involved in the field of study of the TRAASH research project.

Samuel Holzman and Dominic Noll in their keynote paper discuss the reuse of construction materials within a larger system of consumption and waste over thousands of years at the island of Samothrace, utilizing data from ongoing archaeological excavations and ecological field research.

The next four papers deal with the reuse and recycle of material mainly in religious context from the Archaic period until Late Antiquity. A.M.S. Karatas' paper examines the reuse of statues, bases and altars in Greek sanctuaries from the Hellenistic to the Roman Imperial period, focusing on the fact that the bases bearing the dedicatory inscriptions with the honorary statues, which had been erected in the Greek sanctuaries, were reused together or separately. Sophia Baltzoi discusses the aspects of use of a mask in antiquity, the different construction materials, comparing the perishable and non-perishable materials, the reasons that made their use and reuse imperative and their relation to the concept of time. Daria Russo analyzes a relief, found in Pompeii

in the 1950s and published only in 2018. It is suggested that the piece, probably depicting two intellectuals, was carved in Greece in the Hellenistic period and upon reaching Italy, it would have been purchased and then displayed in the caupona of Euxinus. In his paper, Giorgos Doulfis explores the prohibited or controversial reuse of ancient sanctuaries and their material in Late Antiquity. Despite state and religious prohibition, several ancient sanctuaries lost their 'immunity' and, as a result, their buildings or the materials of these buildings were reused by individuals and communities and turned into places of residence or burial, a practice that affected the monumental landscape of Late Antiquity.

The next three papers examine aspects of reusing and recycling material and landscape during the Prehistoric period. Specifically, in her paper, Christina Papoulia explores examples of object re-utilization, such as stone and bone tools, as well as landscape re-occupation. Her objective is to delve into the life-histories of artifacts and sites in the Greek peninsula. These were revisited by the same or different groups of people, including different species like Neanderthals and Homo sapiens. Additionally, she examines the methodological approaches employed by the academic community in revisiting the past and reshaping established narratives. Katerina Glaraki in her paper suggests that in the Myrsini tholos tomb the fragmented funerary receptacles were in secondary use. In Myrsini the use of fragmented burial containers is attested during the Protopalatial period, when the custom of using pithoi and larnakes for burials is well established. The same practice seems also to occur in other cemeteries of this period. The deliberate use of fragmented funerary receptacles corresponds to a *pars pro toto* concept, where the fragmented parts retain their original –before fragmentation– function. Giorgos Sofianos focuses on an understudied subject, the reuse of architectural features and spaces and of artifacts used in buildings of Prepalatial settlements of Minoan Crete. The 'secondary use' examples are examined on both the archaeological material that they employ, e.g., walls, rooms, artifacts, and the purpose that they serve.

The next four contributions examine the reuse and recycle of materials and space from the Archaic period until present at Xanthi Prefecture, area of study of the TRAASH project, and the neighboring island of Thasos. Firstly, Giannis Mourthos focuses on three Thasian sites, the Sanctuary of Pan, the early-Christian basilica in the agora of Thasos and the Aliki peninsula, where one can trace the material manifestations of the transmission and dissemination of ideas that establish social memory shared between the members of a group and over time from generation to generation, that is the reuse of materials and space. Paraskevi Motsiou examines the interrelationship of the functions over uses of the area of 'Valta Zampaki' at Abdera throughout different periods. Her analysis spans from the natural landscape prior to the arrival of Klazomenian settlers, through intermediate cycles of habitation and use, eventual abandonment, restoration to its natural state, and up to the modern period with its agricultural exploitation. Vassilis Demou presents a snapshot from his recent archaeological ethnographic fieldwork in the Prefecture of Xanthi, northeastern Greece; this narrative aims to convey not only the processes, through which discarded metals are collected, sold, and reused, but also the dynamic relationships traced among the different individuals involved in this cycle, including discarders, scrappers, scrap-yard owners and buyers. Lastly, Styliani Raxioni presents a paper that aims to highlight the modern educational role of the folklore museum, as well as its contribution to contemporary societal issues. She uses the reopening of the Folklore and Historic Museum of Abdera as an example, showcasing its promotion of discussion on recycling and the protection of the natural environment. In this context, an educational program was designed and developed for young children and older women: "Recycling tradition: Once upon a time… we made dolls out of rags".

The next three articles are dedicated to the examination of reuse of pottery and mosaic floors in the antiquity and early Christian period. P.H. Segovia analyzes an unattributed vase from the Louvre Museum –an Attic red-figure *chous* dated to about 425–420 BC, more commonly known as *Anthesteria chous*, with the aim of suggesting an alternative thesis on the possible (re)use of some small choes, by interpreting the images depicted on them. Anna Dalgkitsi and Anastasia Angelopoulou discuss the Hellenistic pottery originating from the extra-urban Sanctuary of Poseidon and Amphitrite at Kionia, Tenos. The assemblage reflects cult practices honoring Poseidon Healer and his wife Amphitrite, and its study contributes towards a better understanding of the spatial and architectural changes in the sanctuary during its peak, towards the end of the 2nd – beginning

of the 1st century BC. Lastly, Foteini Kokkini examines case studies that come mainly from Greece and date back to the Roman imperial and early Christian period, and support the fact that the mosaic floors of ancient buildings were also subjected to reuse.

Finally, the last four papers of this volume present case studies of space reuse during the Classical antiquity. Anastasios Kakamanoudis explores the various aspects of the phenomenon of reuse in the necropolis of Aigai, in which around 1200 graves dating from the end of the 2nd millennium BC to the beginning of the 1st millennium AD have been investigated to date. While in the early periods of use of the necropolis the reuse of the burial ground is limited, during the Late Classical and Hellenistic periods the pattern of use of the burial ground is significantly differentiated. In her paper Angeliki Papageorgiou attempts to collect and present all the data related to the importance of the garden as a recycling and reuse environment. Through these findings, she examines the identity and significance of the garden, not only as a cultivating land, but also as a reference point, constantly changing, in order to serve the needs of the society from which it was created. Hannah Smagh investigates the foundation deposits associated with houses in relation to their architectural environment, in order to analyze the impact of these deposits on the configuration and experience of the domestic space. The burial of these foundation deposits has permanently, but invisibly, changed the character of the domestic space, giving it a sacred significance. These practices blurred the boundaries of the sacred and the profane within the home, encouraging a reassessment of the terms that apply to the Greek home and sacred space in the Greek world at large. Lastly, Chryssa Arvaniti and Lena Lytsiou present two stone structures, an *eschara* and a *thesaurus* (treasury), found during the construction of the tram stop in front of the Church of Evangelistria at Piraeus, and discuss the structures' phases of use in relation to their adjacent architectural features.

It is our hope that our diachronic approach to 'rubbish' shall form a paradigm of environmental and material sustainability for present and future application in modern society, and shall inspire and urge other people in the direction of developing, managing and supporting innovative activities related to reuse and recycle.

Nikolas Dimakis and Paraskevi Motsiou

The legacies of construction waste on Samothrace from antiquity to the present

A case study between archaeology and social metabolism

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ABSTRACT

The Greek island of Samothrace, located in the northern Aegean Sea, has been continuously inhabited since about 5500 BC. Samothracian builders, however, imported non-biodegradable building materials in large quantities only during two historical periods, the first during the early Hellenistic period (c. 350–150 BC) and the second during the modern period (c. 1970–2021). Samothrace's insularity limits the flow of materials: it increases the cost of imports, prevents most waste exports and limits options for local waste management and recycling. The artificial harbors, which were built on the island in antiquity and in the 20th century, have significantly changed the building and reuse patterns on the island. A broad historical outline of building on Samothrace, comparing the last 5000 and 100 years, draws attention to the secondary uses of building materials. By quantifying ancient imports of marble and modern imports of concrete, brick, asphalt, steel and plastics, it is possible to compare the scale of the imprint these materials leave on the landscape. A point of alignment between the historical data collected from archaeological excavations and the modern statistics produced by Sociometabolic Research reveals a striking contrast: the estimated average amount of construction and demolition waste produced each year in Samothrace today (10,000 tones) is roughly equal to the total estimate of all marble imported to the island for construction purposes in antiquity.

INTRODUCTION

This conference testifies to the continued upswell of scholarly interest in ancient reuse, repair, spoliation and the many other second lives of archaeological artifacts and historic buildings. The fascination with ancient recycling is a reflexive response to the modern global challenge of waste, the scale of which seems starkly at odds with the past. The remote Greek island of Samothrace offers an ideal case study for contextualizing the reuse of construction materials within a larger system of consumption and waste over thousands of years. The comparison of ancient and modern reuse practices, however, requires a cross-disciplinary dialog between ongoing archaeological excavations and ecological field research. Although these disciplines rely on different forms of evidence and methods of investigation, they may be beneficially combined to offer a diachronic perspective.

Spoliation and repair are two processes central to understanding the prevalence in the archaeological record of architectural elements, inscriptions, and sculpture immured in later buildings (for another recent conference on this topic, see Piesker and Wulf-Rheidt 2020). On the one hand, cases of spolia, where reused elements are prominently displayed in new architectural settings, resonate with the cultural message of continuity and resilience imbued by their second use contexts (Rous2019). On the other hand, ancient inscribed accounts listing monetary values for second-hand building materials leave little doubt that builders of the past were motivated largely by efficiency and economy (Sioumpara 2020). Ancient practices of reuse must be contextualized within larger patterns of consumption. In the terminology of Social Ecology, these materials are recirculated within a social metabolism – a term for the large-scale streams of materials and energy used and expended by a society.

Sociometabolic Research takes as its starting point the dependence of societies on the exchange of materials and energy with natural systems (Haberl et al. 2019). This approach assesses patterns of resource use and waste generation within social and economic systems, highlighting changes over time and across regions. Social metabolism is essential for assessing sustainability challenges, which arise at both the input and output sides of socioeconomic systems through resource extraction and the generation of waste and emissions.

The Greek Island of Samothrace presents a special opportunity for assessing the reuse of building materials over a long chronological span. Located in the northeast of the Aegean Sea (Fig. 1), the island has an area of less than 200km^2, but its mountainous topography generates two distinctive microclimates, one in the north with lush forests and numerous streams and rivers, the other in the more arid south with cereal cultivation and olive trees. These ecological features have warranted the inclusion of two thirds of the island in the Natura 2000 network, a European Union environmental protection designation. The island context effects the generation and treatment of building waste (Deschenes and Chertow 2004; Singh et al. 2023). In particular, the geographic isolation of islands constrains the flow of materials. Materials imported to the island must be recycled, reused, incinerated or deposited in landfills on the island or else exported to the mainland (Eckelman and Chertow 2009). Because exporting waste is costly, small islands such as Samothrace face numerous obstacles to the effective treatment of waste and opportunities for reuse are of great importance (Eckelman et al. 2014; Noll et al. 2019). Social metabolism is central to the current socioeconomic and environmental challenges faced by the island community of *c*. 2800 (Fischer-Kowalski et al. 2020; Noll et al. 2024).

Analyzing the social metabolism of islands, regions for which data can be scarce, requires a combination of methods: larger-scale official statistics are nuanced through modelling, field measurements and interviews (Johnson et al. 2007). The long-term socioecological research project on Samothrace enabled the collection of data to model changes in the social metabolism of the island from 1929 to 2019 (Noll et al. 2019; 2020; 2022). A bottom-up stock modelling approach has been applied to estimate the quantities of in-use building materials, resource requirements and waste from construction and demolition (Noll et al. 2019). In this approach, totals of buildings and infrastructure are combined with documented rates of material and resource intensiveness (assessed for roads per kilometer, building types by area covered, and port structures by volume) with attention to how building methods and maintenance requirements change over time (Müller 2006; Tanikawa et al. 2015; Wiedenhofer et al. 2019).

The more distant past can be brought into communication with assessments of contemporary social metabolism through analogous archaeological methods. Architectural Energetics Analysis, for example, has shown the potential for reliably reconstructing material and labor totals for large-scale building projects through quantities estimation and comparisons with historically documented work rates from more recent centuries (DeLaine 1997). The ruins of ancient structures directly attest to the quantities of building materials and residual waste, but studies of quarrying and building practices have revealed the large scale of waste generated in the initial construction process (Korres 1995). Although rare before the modern era, primary source documents also offer keys to interpreting the cultural significance of cases or reuse.

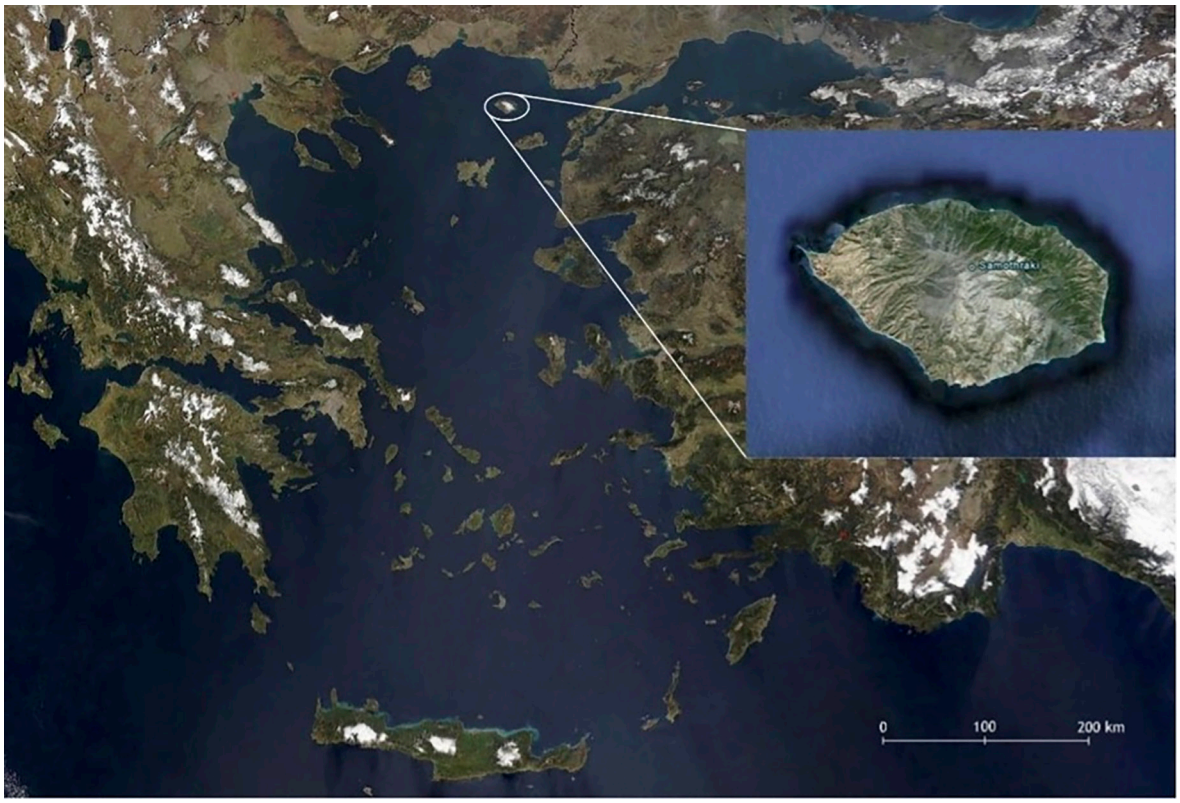

Fig. 1. The Greek island Samothrace (source: nasaimage.org).

REUSING CONSTRUCTION MATERIALS ON SAMOTHRACE IN ANTIQUITY

Samothrace has been inhabited since at least 5500 BC. Excavations led by archaeologist Dimitris Matsas at the site of Mikro Vouni have uncovered settlement extending back to the Late Neolithic period (Matsas 1984). Geomorphological studies of the area have shown that the coastal site once sat at the edge of an ancient lagoon, which likely served as a harbor for the prehistoric settlement (Syrides et al. 2009), at least during the Late Neolithic. Mikro Vouni is an artificial mound covering an area of one hectare – a tell site in archaeological parlance –containing sequential settlements each built on top of its predecessor to produce a stratigraphic sequence 8 m tall. Like the formation process of so many other tell sites, the mound is the product of backfilling, where new habitations took advantage of the building waste of earlier settlements, eventually producing an advantageous elevated position on a coastal promontory. By the 3rd millennium, Mikro Vouni was a small town, with a population estimated at 300–400 inhabitants. Finds from the excavation show a site enmeshed in Aegean trade networks, with obsidian imported from Melos in the Neolithic and bullae stamped and inscribed with Linear A documents in the Middle Bronze Age (Matsas 1995). Construction materials, however, were local. Builders used smooth beach-stones, readily available for use without quarrying or processing for the socles of walls and mud-brick for the superstructures. The use of local stone, only roughly processed, continued through the Early Iron Age, with the construction of megalithic dolmen tombs and Cyclopean-type fortifications for protection of lower-lying settlements and herds (Matsas 2007).

Importing building materials to the island at scale was limited through much of the island's history, due to its lack of harbors. The Roman writer Pliny (4.12.73) awards Samothrace the title of "the poorest of all the [Aegean] islands in harbors". This situation changed for several centuries in antiquity with the construction (probably in the 4th or 3rd century BC) of an artificial harbor at Paleopolis, the site of the Classical polis, although the ancient harbor awaits future investigation. A second harbor was also used in antiquity (Livy 45.6), located

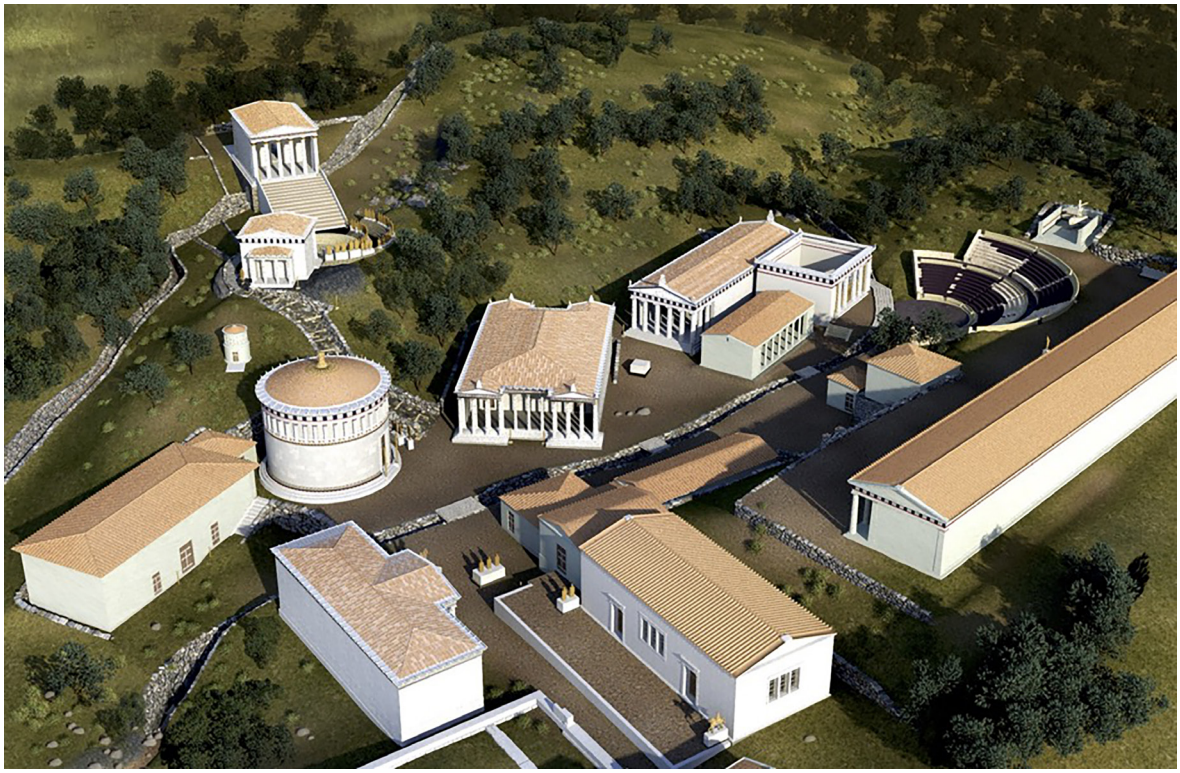

Fig. 2. Virtual reconstruction of the marble buildings in the Sanctuary of the Great Gods, Samothrace in antiquity (© American Excavations Samothrace).

closer to Kamariotissa, but its identification has not yet been confirmed. The Sanctuary of the Great Gods, the site of one of the ancient world's most renowned mystery cults, drew a major influx of building supported by external patronage in a roughly 200-year period, bookended by two important historical events on the island: in the 350s BC, the parents of Alexander the Great, Philip II and Olympias, met and arranged their marriage on Samothrace, and in 168 BC, the Roman navy blockaded the island after the battle of Pydna, in order to capture Perseus, the last Macedonian king. Construction in the Sanctuary of the Great Gods (Fig. 2), beginning probably with Philip II (Wescoat 2010), led to the mass importation of a building material not native to the island, which has left a tangible impact on the landscape: white marble.

During the early Hellenistic period, the Sanctuary of the Great Gods saw the construction of seven major buildings, made from imported white marble: the Hall of Choral Dancers, Dedication of Philip III and Alexander IV, Hieron, Altar Court, Propylon of Ptolemy II, Rotunda of Arsinoe II, Milesian Banquet Hall. Chemical analysis indicates that most of the marble was imported from the Aliki quarries of the island of Thasos, although marble was also brought from Prokonessos and Pentele (Maniatis et al. 2012). Notably, five of the seven marble buildings combined white marble from geographically distant sources. There was an additional major marble building, the construction of which was cut short at the level of the stylobate (Building A), as well as one small architectural addition (the Ionic porch appended to the Dedication), and limestone buildings that used imported marble for the details of the door and window frames (e.g., the Neorion).

As a result of the good state of preservation of these buildings, it is possible to estimate the original total quantity of marble imported to the island. The volume of stone has already been calculated for the Nike Monument: the statue of winged victory was sculpted from four to five tons of marble from Paros and the ship base was built from 30 tons of Lartian stone from Rhodes (Stewart 2016, 403). In a forthcoming article (Holzman forthcoming), an estimate for the quantities and transportation logistics for the Propylon dedicated by Ptolemy II are presented, based on 3D modeling. This ceremonial gatehouse into the sanctuary comprised almost 400 m^3 or 1000 tons. The volume of marble in the Rotunda of Arsinoe II is simpler to estimate, as the structure's circular design utilized a limited number of uniformly sized blocks. It originally contained about 500

Fig. 3. Close-up of the marble-chip pavement of the Hall of Choral Dancers, likely a second use of construction waste generated by the project itself (photo by the author).

m^3 or 1300 tons. Ancient marble blocks were not transported in their fully carved state, but arrived from the quarry with a protective outer coating of material to shield them from damage. This protective layer (*apergon*), which was carved off at the worksite, could increase the weight of each block by as much as 50% (Korres 1990). The on-site finishing of blocks, therefore, entailed that almost one third of the weight of marble imported to the island became construction waste in the form of marble chips. Taking the Propylon and Rotunda as median examples, the seven marble buildings of the sanctuary represent the importation of approximately 10,000 tons, or ten kilotons (kt), of white marble in a 200-year period.

Some construction waste was utilized immediately: three buildings in the sanctuary have floors with pavements made of marble chips. Because the Hall of Choral Dancers was the sanctuary's first marble building, the marble chip floor pavement of this structure must represent a second use of the masons' working chips from that project (Fig. 3). Many of the sanctuary's structures, even some of those with marble exteriors, had plastered interiors, and marble construction waste may have been burnt for lime at the time of construction. As buildings fell into disrepair, stone blocks were given new uses with only minor modifications: in the Hestiatorion, for example, marble roof tiles from the Dedication of Philip III and Alexander IV were reused upside down as a gutter in the floor, to sweep up after feasts (Wescoat 2017, 128). Ultimately, in the post-antique period, many marble blocks from the ruined buildings were downcycled into lime. In some cases, the walls of ancient structures were reused *in situ* to build up limekilns (Lehmann 1953, 12; Wescoat 2017, 24, 308–9). The downcycling of ancient marble blocks as building materials continued into the mid-20th century, when –during the Bulgarian occupation of the island in the Second World War– excavated marble blocks from the Rotunda of Arsinoe II were smashed up to build a staircase (Lehmann 1948, 46).

It appears that less than half of the stones from the superstructures of buildings in the sanctuary remain at the site. From the 100-meter-long Stoa, for example, 1700 limestone blocks were recovered during excavation; yet, these constitute only a fraction (roughly 20–30%) of the original building blocks from above the level of the stylobate. Blocks have been dispersed into the environment, primarily washed downhill, where they are found in streambeds and even on the beach. Many of the absent blocks, however, were quarried for second use. It is, nevertheless, difficult to assess a percentage reuse rate, because of the fragmentary nature of the material. In the town of Chora, for example, one can see embedded in the wall of an in-use building a small marble fragment with a drafted margin that distinguishes its origin from one of two buildings in the sanctuary, the Hieron or Propylon of Ptolemy II (Fig. 4). These fragments were reused because they provided advantageous building materials without extraction or import costs. Often cases of reuse were not for reasons of economy alone, but possessed profound cultural.

Fig. 4. Fragment of Thasian marble with drafted margin from the Hieron or Propylon of Ptolemy II in the wall of an in-use building in Chora (photo by the author).

Buildings containing reused and downcycled materials were often of central significance to communities. In his report on the 1873 mission to Samothrace, Alexander Conze remarked that the traditional houses of Samothrace used lime plaster sparingly, and then only for covering interior walls (Conze et al. 1875, 35). He proposed that the lime kilns found in the sanctuary had been built to burn ancient marble blocks specifically for church building. The *katholikon* of the Monastery of Christos (probably built in the first half the 14th century) contains the most extensive marble spolia. The white marble blocks were reused in combination with dark local stones and red bricks to create eye-catching polychromatic patterns. The prominent inclusion of three ancient inscriptions with lists of *theoroi* –religious ambassadors to the sanctuary of the Great Gods– displayed the long history of religious devotion on the island (Matsas and Bakirtzis 2001, 81). These instances of spolia may well have played an important part in the construction of local histories and identities. Two records of local histories from Samothrace attest to the significance of reuse in different periods on the island.

The first-century BC Greek writer Diodorus Siculus records a local history told by the Samothracians, which is worth quoting at length (Diodorus 5.47.3-5, translation Oldfather 1967, 229–31):

> *"The Samothracians have a story that, before the floods which befell other peoples, a great one took place among them… and made no small amount of the level part of the land of Samothrace into a sea; and this is the reason, we are told, why in later times fishermen have now and then brought up in their nets the stone capitals of columns, since even cities were covered by the inundation. The inhabitants who had been caught by the flood, the account continues, ran up to the higher regions of the island; and when the sea kept rising higher and higher, they prayed to the native gods, and since their lives were spared, to commemorate their rescue, they set up boundary stones about the entire circuit of the island and dedicated altars upon which they offer sacrifices even to the present day."*

There is no evidence of submerged prehistoric cities on Samothrace, but ancient local accounts of Samothracian fishermen pulling recognizable architectural debris from the sea may very well have a kernel of truth. In the archaeological site's beachside parking lot, one can now see a number of water-worn architectural members from Hellenistic buildings that have been recovered from the shoreline, where they were transported over time by flooding and erosion. It is conceivable that earlier building debris had already been washed down to the shoreline by the time of Diodorus, where it was ripe for reinterpretation. The mention of "boundary stones" and "altars" set up on the island testifying to the high-water mark and last refuge of the Samothracians' antediluvian ancestors, could well be interpretations of the Early Iron Age hilltop settlements ringed with circuit

walls of large boulders like Vrychós or the megalithic dolmen tombs at Yalómandra and Selládha (Matsas 2007). In these stories, the ruins of prehistoric settlements are utilized for cultural prestige in the Roman world.

The second account is that of the Italian humanist Cyriac of Ancona, who visited the island of Samothrace in October 1444, where he was hosted by John Laskaris, the governor representing the island's Genoese ruler, Palamede Gattilusio (Lehmann 1973). Cyriac toured the ruins of the Hellenistic city at Paleopoli and after hiking through the ruins, Laskaris took Cyriac to see the newly built tower, where "we saw at the tower itself numerous ancient artfully sculpted dancing nymphs; and we discovered on every side numerous other extraordinary remains of the antiquity of this great city…" (*Diary II* 11; translation Bodnar 2002, 101). The sculpted dancing nymphs described and drawn by Cyriac as the foremost pieces in Gattilusio's collection of antiquities are well-known artifacts, two blocks of the frieze of the Hall of Choral Dancers. These blocks were removed to the Louvre in 1863 and brought back to the island in 1955 on permeant loan as part of the exchange to exhibit the hand of the Nike of Samothrace in Paris (Lehmann and Spittle 1982, 8).

During his time on Samothrace, Cyriac transcribed inscriptions that he saw built into the tower, as well as those collected "in the royal garden by the sea" (*Diary II* 19, translation Bodnar 2002, 103). Cyriac's acute antiquarian attention was admittedly exceptional, but it is evident that the appeal of connecting oneself with the past through spolia was more widely shared, including by the Genoese prince, who had assembled "very old inscriptions in Greek, and even in our own countrymen's lettering" (*Diary II* 14, translation Bodnar 2002, 101). This firsthand narration presents the 15th century tower in Paleopolis as a private art collection, in which stones attesting to the antiquity and cosmopolitan nature of ancient Samothrace were assembled. The Gattilusi tower and royal garden were forerunners to the island's archaeological museum.

Evidence for the reuse of building materials on Samothrace extends back to prehistory. Two centuries of intensive building activity between the 4th and 2nd centuries BC led to the importation of an estimated 10 kt of white marble. Nearly two and a half millennia later, this material stock is still largely present on the island, a significant portion of it reused or downcycled as building materials in dozens of subsequent structures, though a large share of the material has been dispersed by erosion and other natural processes. The history of building on Samothrace and its legacies lasting thousands of years serves as a basis for comparison with the contemporary challenges of waste management on the island.

SAMOTHRACE'S CONTEMPORARY BUILDINGS AND INFRASTRUCTURE AND THE CHALLENGE FOR A CIRCULAR ECONOMY

The past century marks an era that is unprecedented for the island of Samothrace, not simply in the expanded scale of its construction activities, but in the total flows of materials and energy involved in construction, maintenance and waste generation. The expansion of the island's social metabolism from 1929 to 2019 can be charted (Fig. 5), highlighting the contemporary challenges associated with this development. The island's material stocks, that is all buildings and infrastructure, have doubled and redoubled in the past 90 years.

During the last 90 years, materials bound in buildings and infrastructure grew five-fold from 200kt to 1000kt. In 1971, a new port was built, accommodating larger ships and thus larger quantities of imported goods. This event marks a distinctive change in the social metabolism of the island, as did the accession of Greece to the EU in 1982. The five-fold material stock expansion is also reflected in resource consumption patterns. The construction of buildings and infrastructure requires resources. Once buildings and infrastructure are set in place, however, they require maintenance, thus shaping patterns in the use of materials for decades to come. Figure 6 shows Samothrace's estimated Domestic Material Consumption (DMC) in four categories: biomass, fossil fuels, metals and non-metallic minerals – the last category comprising most building materials.

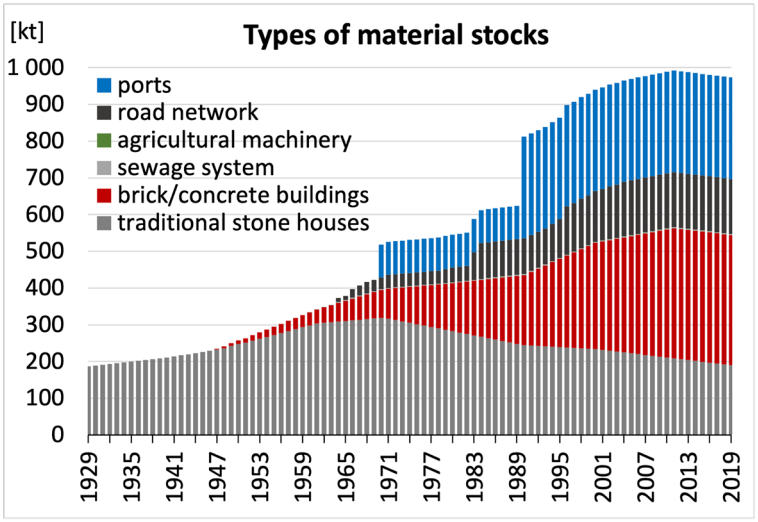

Fig. 5. Expansion of material stocks from 1929–2019 (Noll et al. 2021). Grey indicates traditional houses built of stone, red modern houses of brick and concrete, dark blue the paved road network, and light blue represent port structures.

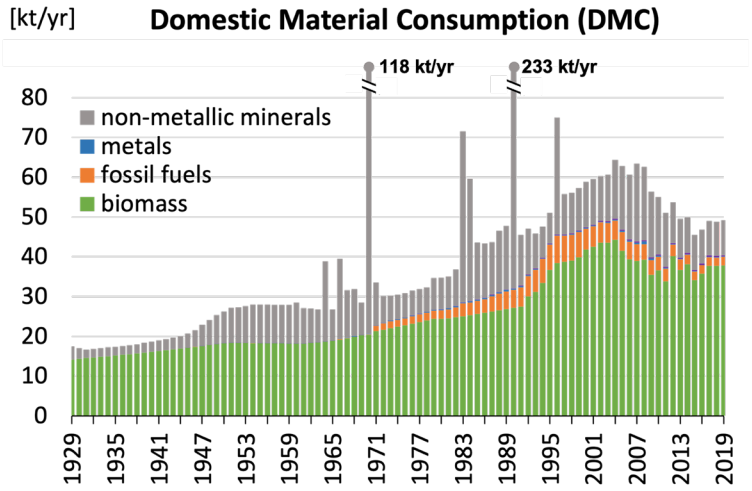

Fig. 6. Domestic Material Consumption (DMC) from 1929–2019 (Noll et al. 2021).

From 1929 to 2019, DMC grew four-fold, from 16 kt/yr to 50 kt/yr (Noll et al. 2022). Despite the wide range of materials imported to Samothrace, the island's metabolism has always largely been shaped by biomass consumption. The large share of biomass consumption reflects the centrality of livestock, particularly sheep and goats, to the island economy. In 1929, the island's metabolism was primarily defined by agriculture. In the 1950s, construction accelerated, a phenomenon reflected in the escalating quantities of non-metallic minerals. The construction of the port in 1971, its subsequent extension, and the construction of a second port in 1991 required quantities of materials of a greater order of magnitude than annual consumption patterns of other years (the two grey bars in Fig. 6 that are 'off the chart'). In 1971, the island started importing fossil fuels for local electricity production with diesel engines and the increasing use of cars and machinery. Since the island was connected to the mainland grid with a deep-sea cable in 2000, the use of fossil fuels has declined as domestic oil heating systems are replaced and diesel generators are dismantled. Resource consumption peaked in the years after 2000 and it seems the growth of the island's metabolism has leveled off. The global financial crisis and Greek debt crisis may well have played roles in this change as well. Is this a new stable metabolic level or will resource consumption change further? This question is central to the long-term sustainability of the island.

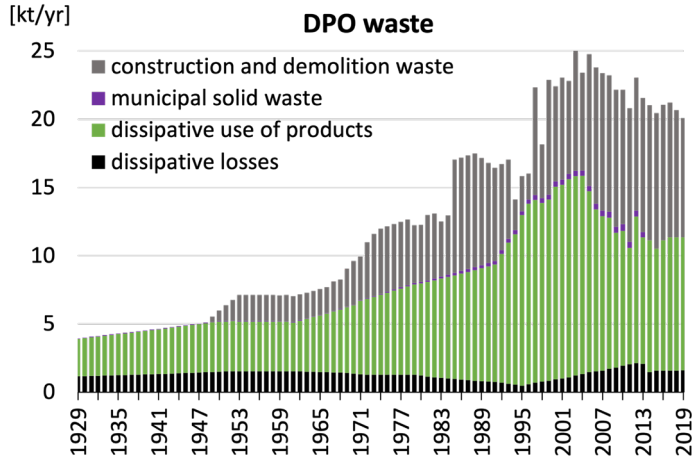

Fig. 7. Domestic Processed Output (DPO) waste from 1929–2019 (Noll et al. 2021).

Construction activity along the coast has resumed following years of stagnation since the onset of the Greek financial crisis in 2010 and may indicate a continuation of the trend of expansion.

If material consumption increases, it will either manifest as societal stocks, resulting in net expansion, or end up as domestic processed output (DPO) of waste and emissions (Fig. 7). Annual amounts of waste generation grew from about 0.3kt/yr in 1929 to 10kt/yr today. Three quarters of this waste is in the form of aggregates that can only allow for downcycling – and then depending on the domestic availability of the required technology. Recycling of building materials on Samothrace is marginal and only done at large scale during road construction in the form of backfilling. The solid waste stock on the island today is approximately 400kt. If current practices continue, the waste stock on Samothrace will outweigh all in-service material stocks between 2070 and 2080.

This projection of material use and waste generation shows the magnitude of the challenge the community of Samothrace faces. The island only exports a small fraction of waste, namely municipal solid waste collected directly from households. Exports come at high costs, and there is no easy solution in sight for either bulk waste or construction waste. Most of this waste ends up on informal dumping grounds, most prominently next to the island's capital, Chora (**Fig. 8**). Although construction and demolition waste may contain fractions of toxic materials such as plastics and colorants, the long-term impact is largely cosmetic. Although superficial, this is also a concern for an island economically dependent on tourism. One third of the cumulative construction and demolition waste comes from fieldstones of abandoned stone houses. The deterioration of stone houses does not represent an environmental hazard and fieldstones could eventually be reused as building materials—as they have been throughout the island's history. Many of these houses are remote and are unlikely to be reused given the difficulty of accessibility and divergence from current settlement patterns. To achieve a sustainable development path for local infrastructure, long-term solutions must focus on a circular economy, with potentials for domestically reusing and recycling waste, limiting further stock expansion, reducing the overall scale of the island's social metabolism, and implementing legal frameworks that prioritize these targets (Noll et al. 2019; 2022).

Fig. 8. Informal collection site for construction and demolition waste in the outskirts of Chora, Samothrace's capital (photo by the author).

LEGACIES OF CONSTRUCTION WASTE ON THE ISLAND OF SAMOTHRACE

Setting ancient and modern datapoints in dialogue reveals three salient points of comparison: (1) artificial harbors built in antiquity and the 20th century, which are themselves among the largest construction projects undertaken on the island in their respective eras, have substantially shifted building practices. (2) The current rate of annual generation of construction and demolition waste on Samothrace –for which there is currently little infrastructure to support reuse or export for recycling– is ten kilotons per year. This annual figure is an equivalent quantity to the estimate of all the marble imported to the island during its most famous historical period of activity. (3) Since the Neolithic settlement at Mikro Vouni, inhabitants of the island of Samothrace have been living amidst and on top of the ruins of earlier settlements, often making new meanings for column capitals dredged from the sea or blocks inscribed with foreign alphabets. Modernity has brought an unprecedented expansion to the island, to the point where the modern far overshadows the ancient. The short use life of modern building materials and the limited possibilities for recycling, however, presage an imminent reversal. If trends continue, in 50 years there will be ton-for-ton more architectural debris on the island than building materials in actively used structures. This estimate marks a horizon for reuse and recycling: one can only reuse as much material as there is use for. This point will mark a return to a manner of living familiar from the past, surrounded on all sides by the ruins of earlier settlements – with the exception that those ruins will be of our own time.

We are often moved and inspired by the scale of ruined buildings and infrastructure from antiquity. Spolia and other cases of reuse still reverberate with symbolic meanings. The sheer dimensions of modern waste generation, however, are rather more difficult to appreciate. What legacies will contemporary building have

and what materials will remain for millennia to come? Samothrace presents a microcosm of processes and challenges afoot on the mainland, which are set into high relief by the constraints that insularity places upon the flow of materials. Setting archaeological and sociometabolic research in dialogue yields cross-disciplinary benefits, laying bare the entanglement of antiquity with contemporary tourism, economy and infrastructure in Greece, and reinforcing ecological forecasts with long-term historical perspective.

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