

THE UNESCO 14TH CENTURY FORTIFICATIONS OF CERCA NOVA (ÉVORA, PORTUGAL): PROVENIENCE AND CLASSIFICATION OF GEO-MATERIALS AND VASCULAR PLANTS INVENTORY

AS FORTIFICAÇÕES UNESCO DA CERCA NOVA DO SÉCULO XIV (ÉVORA, PORTUGAL): PROVENIÊNCIA E CLASSIFICAÇÃO DE GEOMATERIAIS E INVENTÁRIO DE PLANTAS VASCULARES

Fabio Sitzia⁽¹⁾

Abstract

The historic centre of Évora city (Portugal) is classified as UNESCO World Heritage Site since 1986. It is surrounded by fortifications built during the 14th century (Cerca Nova) and classified as National Monument since 1922. After their construction, at least five restoration interventions (15th, 16th, 17th, 18th and 19th centuries) were executed.

In this research, a lithological characterization of the construction materials has been conducted. The classification of the different rocks observed at Cerca Nova give archaeometric information as proveniences and ancient extraction areas. Geological data suggests a supply of geomaterials mainly from local quarries and from scattered boulders in the countryside of the city. In extremely limited quantities, some lithologies such as marbles and limestones, not belonging to local outcrops, were used. These are most likely spoliations materials, whose act was widely used in the medieval period.

In addition to the characterization of the lithological materials, the inventory of the vascular plants growing on the fortifications recognized 42 taxa belonging to 26 families and 34 genera. Half of the 42 taxa verified are represented by native plants and the other half are represented by exotic species. The latter includes nine alien invasive taxa, despite the individuals belonging to this group of species are limited to some portions of the masonry and represent a rather low percentage when referring the sample. The origin of the alien taxa is mainly from the tropical-American biogeographical region.

Keywords: Portuguese rocks, Granitoids, Provenance, UNESCO, Vascular flora, Alentejo, Invasive plants.

Resumo

O centro histórico da cidade de Évora (Portugal) encontra-se classificado como Património Mundial da UNESCO, desde 1986. Esta zona está rodeada por fortificações construídas durante o século XIV (Cerca Nova), classificadas como Monumento Nacional, desde 1922. Após a sua construção, foram levadas a cabo pelo menos cinco intervenções de restauro (nos séculos XV, XVI, XVII, XVIII e XIX).

Nesta investigação, procedeu-se a uma caracterização litológica dos respetivos materiais de construção. A classificação das diferentes rochas identificadas na Cerca Nova forneceu informações arqueométricas sobre proveniências e áreas de extração antigas. Os dados geológicos sugerem um fornecimento de geomateriais principalmente de pedreiras locais e a partir de blocos de rocha dispersos pela periferia da cidade. Foram utilizadas também algumas litologias, como mármore e calcário, em quantidades extremamente limitadas, que não pertencem aos afloramentos da região. Tais litologias são muito provavelmente materiais de espoliação, prática muito comum no período medieval.

Além da caracterização dos materiais litológicos, o inventário das plantas vasculares que crescem nas fortificações permitiu identificar 42 taxa, pertencentes a 26 famílias e 34 géneros. Metade dos 42 taxa identificados estão representados por plantas nativas, e a outra metade, por plantas exóticas. Estas últimas incluem oito espécies invasoras, que se encontram limitadas a algumas partes da alvenaria, representando uma percentagem bastante baixa relativamente ao total da amostra. Verificou-se ainda que a origem dos taxa exóticos é, principalmente, a região biogeográfica tropical-americana.

Palavras chaves: Rochas portuguesas, Granitóides, Proveniências, UNESCO, Flora vascular, Alentejo, Plantas invasoras.

(1) HERCULES Laboratory and IN2PAST, Associate Laboratory for Research and Innovation in Heritage, Arts, Sustainability and Territory. Institute for Advanced Studies and Research. University of Évora. Largo Marquês de Marialva, 8, 7000-809 Évora (Portugal). Geosciences Department, School of Sciences and Technology, University of Évora, Rua Romão Ramalho 59, 7000-671, Évora (Portugal) | E-Mail address: fsitzia@uevora.pt

1. Introduction

The city's fortifications of Évora, chief town of Évora district (Central Alentejo, Portugal) (Fig. 1), consist of two concentric perimeters. The internal one (*Cerca Velha* in Portuguese) dates from the Roman period (LIMA, 1996). The external one (*Cerca Nova* in Portuguese), as highlighted in Fig. 2, stretches for some kilometres and is punctuated by several gateways and towers. The Cerca Nova is an important part of the historical centre's architecture and provides interesting insights into the city's rich past.

The state of conservation is adequate due to the frequent monitoring works and ordinary maintenance. Extraordinary interventions were carried out between 2022 and 2024 following the heavy rains occurred in November 2022. A significant portion of the wall on the west side, at risk of overturning, was then secured.

The granitoid rocks used for the building of the external fortifications are overall resistant but sometimes suffers from a mild sanding process (SITZIA, 2022).

In general, the parts of the masonry that are threatened by the weather are the bedding mortars, depending on their composition and hydraulicity (BALOG *et al.*, 2016; O'BREIN *et al.*, 1995; MARAVELAKI-KALAITZAKI *et al.*, 2003; FABIO *et al.*, 2020). In some cases, the differential erosion between mortars and stone's ashlar causes the risk of collapse. This process of "scaling" takes place mainly in the lower parts of the fortifications where the synergic action of salt crystallization, capillary rising, rebounding and stagnant water are accounted for (ARGIOLAS, 2020; LISCI *et al.*, 2022). Areas where this process is well evident are located at Alconchel gateway (*Porta de Alconchel* in Portuguese) where both towers were subjected to a restoration intervention in February-March 2024. In conditions of severe deterioration, when a restoring intervention is no longer attainable, deteriorated rock elements or mortars are often replaced with new materials.

Regarding stones, the architect or conservator may choose to replace the rock with a "geological analogue" or an "aesthetic twin" that is geologically different from the original one. In the case of Cerca Nova renovation, "geological analogues" were used. Although the "aesthetic twin" does not require particular studies, finding a "geological analogue" requires a petrographic study for understanding the exact provenience (COLUMBU *et al.*, 2020) and to obtain archaeometric information about the original materials (BARONE *et al.*, 2013; HARMON & CRAIG, 1972). In the case of weathered mortar, the intervention could be done by using a mortar repair with analogue or different composition than the original (SCHUEREMANS *et al.*, 2011; TÖRÖK & SZEMEREY-KISS, 2019). At Cerca Nova, the bedding mortars are colonised by higher plants that, with their root system, exert a mechanical biodeterioration (COZZOLINO *et al.*, 2022; MISHRA, *et al.*, 1995). The presence of vascular plants on the Évora fortification has always been tolerated despite their harmful action being known. Their presence and their seasonal inflorescences gave a "romantic" aspect to the wall during springtime.

In 2021, a full disinfestation activity took place by the municipality. However, the results were only temporary. To date (2024), the vegetation cover on the wall, is quantitatively similar to the pre-disinfestation's one. A noticeable problem is the growth of alien plants on the wall, which also have remarkable degradation capabilities. Among these, we identify the *Ailanthus altissima* Mill., commonly called tree of paradise, native to northeast and central China, and Taiwan (KOWARIK & SÄUMEL, 2007). Several studies have already detected its presence in Portuguese territory, classifying it as invasive alien plant (DUARTE *et al.*, 2020; LOURENÇO *et al.*, 2021). It produces a large number of seeds by wind-dispersion and prefers nutrient-rich, loamy soils, but can grow on nutrient-poor soils (DUARTE *et al.*, 2020).



Fig. 1. Location of Evora city within the Iberian Peninsula. Satellite photo by Google Earth.

Fig. 1. Localização da cidade de Évora na Península Ibérica. Foto por satélite do Google Earth.

The growth capacity of vascular plants is remarkable and is essentially linked to the growth substrate and its chemical characteristics (HOSSEINI *et al.*, 2021). Vascular plants can be divided into acidophilic and basophilic (RAY *et al.*, 1983). The pH of the substrate affects the absorption of nutritive elements such as Ca, Fe, Zn and Cu. Acidophilous plants are botanical species requiring acidic soils, with a pH always lower than 7 (RAY *et al.*, 1983). Conversely, basophilic plants require soil with a neutral pH or greater than 7. Plants that thrive in alkaline soils are often referred as "basophile".

The characterization of higher plants and general "biodeteriogens" on archaeological ruins is a well-known topic in the literature (ELGOHARY *et al.*, 2024; TRAVERSO, 1898). In Italy, for example, some investigations have been carried out in the archaeological areas of the Roman countryside by using the *Braun-Blanquet* phytosociological method (LUCCHESI & PIGNATTI, 2009). It has been detected four main types of vegetation growing on the substrate: i) ruderal nitrophile vegetation; ii) vegetation that is likely to be trampled on: floors, paths and roads; iii) grass vegetation growing on walls: vertical wall faces, dry or damp, and on the tops of walls; iiiii) shrubby and arboreal woody vegetation. Other studies focused on the floristic, phytosociological analyses and observations on roots interactions with monuments, also propose a risk and vulnerability multifactorial index (CANEVA *et al.*, 2023). During the process of plant's colonisation on the archaeological ruins, pioneer plants that cause little damage are replaced by more detrimental plants such as small shrubs or trees (LISCI *et al.*, 2003). Botanists have long been interested in vascular plants growing on Cultural Heritage's buildings in Europe, (CANNARELLA, 1909; ANZALONE, 1951), North Africa (DABGHI *et al.*, 2021), North and Central America (PAVLIK *et al.*, 2021), and Asia (HOSSEINI *et al.*, 2021).

2. The fortifications of Cerca Nova: historical background

The city of Évora (European Capital of Culture 2027) is known for its well-preserved historic center. In 1986, this latter has been designated as World Heritage Site by UNESCO according to the criteria ii-cultural (*Testimony of a considerable cultural change in a given period both in the archaeological and architectural fields as well as in technology, art or landscape*) and iv-cultural (*Offering an outstanding example of a type of architectural or landscape or technological construction illustrating one of the periods of human history*) (<https://whc.unesco.org/en/criteria/>).

As mentioned above, the internal fortification – Cerca Velha – boasts Roman-Medieval origins and is fortified with numerous towers featuring square, circular, and polygonal designs. Additionally, it is punctuated by several gates strategically placed along the main thoroughfares. The Roman Arch of D. Isabel (*Arco Romano de D. Isabel* in Portuguese) stands as a quintessential component of the city's defensive perimeter, adhering meticulously to Roman architectural standards, evident even in its masonry and distinctly Roman-style walkway. It represents a legacy of that time according to the *Instituto de Gestão do Património Arquitectónico e Arqueológico (IGESPAR)*, (<http://www.igespar.pt/pt/>).

It is estimated that Cerca Velha surrounded an area of approximately ten hectares and was almost two thousand meters long (SIMPLÍCIO, 2023). It was built in the 3rd century, during the period of Romanization, and its reconstruction at the beginning of the 10th century, in the middle of Islamic times, is particularly documented (GARCIA BELLIDO, 1971). The 10th century represents the transition period from emirate (757-929 AD) to caliphate of Cordoba (929-1031 AD) (RAHMAN, 2008).

The external fortifications of Cerca Nova, considered in this study, are highlighted in Fig. 2. Their emergence stemmed from the expansion of the residential zone beyond the confines of the Cerca Velha, necessitating the protection of this extended nucleus. D. Afonso IV, King of Portugal, ordered the construction of Évora's Cerca Nova in the 14th century. The fence is made of the towers and walls that mark the limits of the medieval city (Fig. 2).

Only concise information is available about the restoration works of the 15th and 14th centuries, although they can be attributed to campaigns of adaptation of cities, strengthening of defensive structures due to the increasing use of firearms and artillery. These works were carried out under the rule of King D. Afonso V (1438-1481) and King D. João II (1481-1495) (PERES, 1969; LIMA, 1996).

In the following restorations (17th and 18th centuries), the walls were further renovated in Manueline style. This period saw the addition of towers and bastions, along with enhancements to the city gates to better address the siege techniques of the era. In these intervention, Cerca Nova was reinforced with some advanced bulwarks (ESPANCA, 1945; MIRA & BALAESTROS, 1999).

Over the centuries, the military importance of the walls declined, and many sections fell into disrepair. However, in the 19th century, there were initiatives to preserve and restore the walls as a historical and cultural heritage. These interventions aimed to consolidate existing structures and restore parts of the walls that had collapsed or were severely damaged. Most of these operations continued in the 20th century. In this period, during António de Oliveira Salazar government (*Estado Novo*) (GORI, 2018), battlements were added at Cerca Nova to give the idealized historical image of the town. These interventions were often characterized by an approach that combined historical preservation with elements of stylistic reconstruction, which led to the addition of architectural features that were not necessarily present in the original structures.

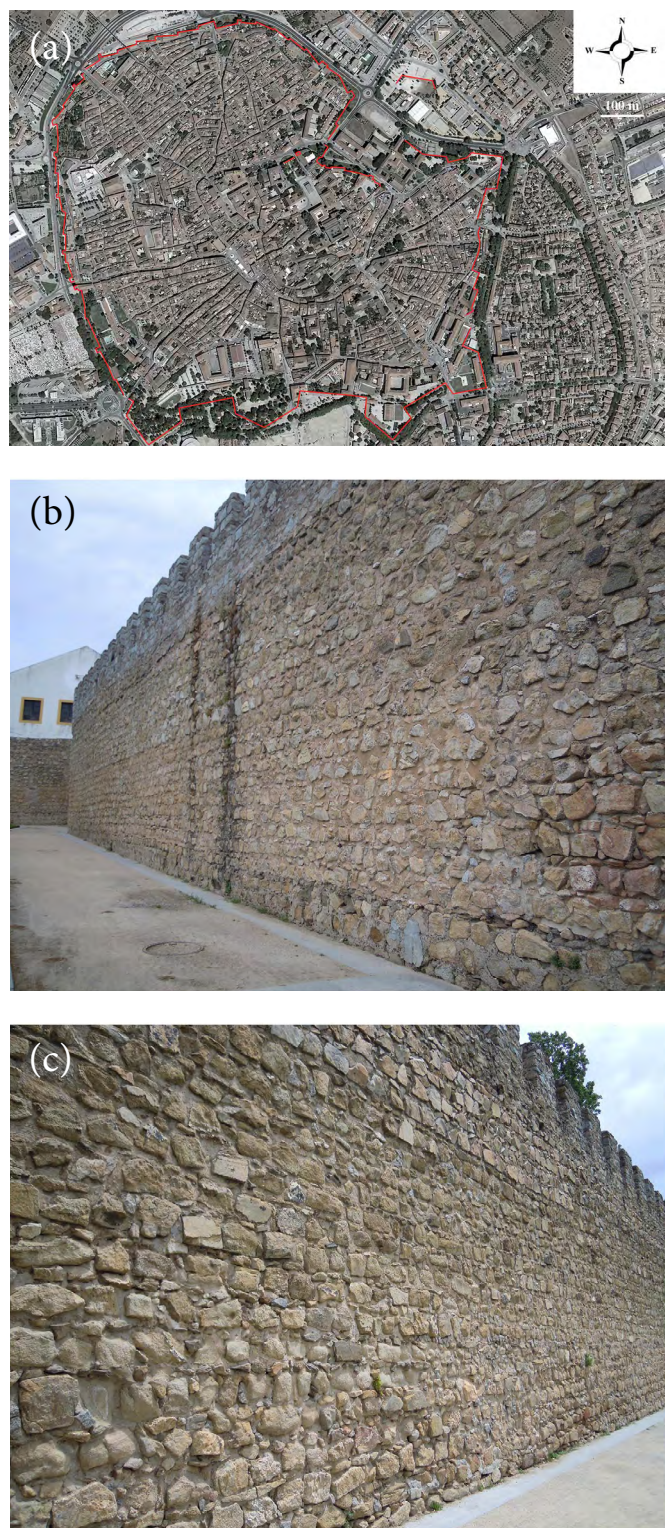


Fig. 2. (a) Cerca Nova perimeter by satellite observation; (b, c) Fortifications in the west side of the city.

Fig. 2. (a) Perímetro da Cerca Nova por observação de satélite; (b, c) Fortificações na zona oeste da cidade.

3. Materials and methods

Given the impossibility of collecting samples from the monument, the rock materials were recognized by visual methods and comparing the *in situ* material with the geological outcrop. On the walls, the height of the observations of the rock materials, as well as the vascular plants, was no more than 3 meters.

The taxonomic and nomenclatural background of the current analysis, mainly for what regards the alien taxa, is the latest updated checklist of the Portuguese alien flora (<https://invasoras.pt/pt/especies-invasoras-portugal>). The native flora has been recognized by consulting flora on online database at <https://flora-on.pt> and research papers on the same issue (PEREIRA *et al.*,

2016; SEQUEIRA *et al.*, 2011). The status of invasiveness has followed the legislation in force in Portugal – Decree-Law n° 92/2019 for Mainland and Madeira and Regional Legislative Decree n° 15/2012/A for Azores.

Regarding biological forms, *Raunkiaer life form classification* (JUST & RAUNKIAER, 1934) has been followed. The geographic origin of the introduced plants is based on the online database <https://powo.science.kew.org>.

Both rocks and vascular plants observations have been performed during the period July-August 2023.

4. Results and discussions

4.1 Rock material substrate characterization and provenance

A large portion of the rocks used in the construction of the wall are of local origin and geologically attributable to the Évora Massif, located in the Southwest of Iberia Peninsula (CARVALHOSA, 1983; PEREIRA *et al.*, 2007). The Évora Massif corresponds to a geological unit within the Ossa-Morena Zone (OMZ), one of the major western divisions of the Iberian Variscan Orogen (CARVALHOSA, 1983). The Variscan or Hercynic orogeny is the name given to the process that led to the rise of a mountain range in particular in Western Europe and the North and Northwest of Africa, during the Late Paleozoic (FRANKE *et al.*, 2020; KRONER & ROMER, 2013).

The Évora Massif is mainly composed of Ediacaran, Cambrian and Ordovician lithologies (CHICORRO *et al.*, 2008; CORDANI *et al.*, 2006), affected by medium and high-grade metamorphism. Extended mafic to felsic intrusive bodies are locally present (MOITA *et al.*, 2009).

According to the geological map of Évora, in the scale of 1/50000 (MATA *et al.*, 1969), the urban center of the city is built on orthogneisses, granitoids, and migmatites (γZ in Fig. 3), dated back from the Lower Carboniferous. The gneisses (Fig. 4a) result from a solid-state deformation of pre-existing granodiorites at high temperatures, forming a white-dark layered rock due to mineral segregation (SAWYER, 2008). These rocks are extensively used throughout the perimeter of the fortifications but are especially employed in the NW perimeter, near the gateway of Velha de Lagoa. Migmatites are randomly present throughout the perimeter of the wall (Fig. 4b). Very interesting examples of migmatite regular ashlar are visible in the SE portion of Cerca Nova, near the city hospital. Sometimes the ashlar of migmatites consist only in the melanosome (darker fraction), or only the leucosome (whitish part).

In the Western part of the city, a geological contact with NW-SE orientation between the aforementioned lithotypes and the Hercynian granitoids is present. These granitoids are represented by different *facies* like coarse/medium grain porphyritic granites ($\gamma\pi g$ in Fig. 3) and coarse/medium grain porphyritic quartz diorites, granodiorites ($\Delta\gamma t$) (CARVALHOSA *et al.*, 1969; MATA *et al.*, 1969). Other Hercynian granitoids consists of not-porphyritic fine grain granites ($\gamma\pi'f$), fine grain not-porphyritic quartz-diorites, granodiorites ($\Delta\gamma f$), and not-porphyritic medium grain quartz diorites, granodiorites ($\Delta\gamma m$). Locally, leucogranitic *facies* are identified (CARVALHOSA *et al.*, 1969). The above mentioned lithologies could be found in outcrops as classical commercial “grey granitoids” and as well as “golden granitoids”. These lithologies are quite common

in the wall (Fig. 4c). Granodiorites, quartz diorites especially medium grain size seems to be mainly used in the recent restoration work of the fortifications.

The leucogranites are probably the most represented stones (together with the granodiorites) at Cerca Nova and seem to represent the *facies* most prone to weathering (Figs. 4d and 4e).

In the outcrops, the above-mentioned Hercynian granitoids are often associated with pegmatitic and aplitic veins and masses (γap in Fig. 3). Both these materials are often found in the walls as shown in Figs. 5a and 5b, respectively. In Fig. 5c, an irregular ashlar of hornfels is shown, although these lithologies are rarely found in the wall. In the field, the outcrops of hornfels are recorded in the East side of the city (Z' in Fig. 3). In the Évora massif, the hornfels represent the results of metamorphic processes at the expense of pre-existing diorites (LOPES *et al.*, 2000).

Occasionally on the wall, diorites and gabbros (Figs. 5d and 5e) were detected. Fairly widespread ashlar are found along the west side of the fortifications. In the countryside, gabbros and diorites are mapped in two main outcrops located outside the city southwards (Fig. 3).

In addition to the aforementioned rocks, which represent the majority, other lithologies, in meaningless percentages, have been found at Cerca Nova. Among these, marbles coming from the *Trigaches-São Brissos* formation (in Beja district, 53 km S of Évora) (Fig. 5f), together with saccharoidal white marbles, probably coming from the area of the Estremoz anticline (Fig. 5g), were recognized. In this last case, the term “probably” indicates that these marbles can also have other origins, like, for example, Carrara (Italy). The use of Carrara marble has been documented in Southern Portugal during Roman times, simultaneously with Estremoz marbles (LOPES *et al.*, 2000).

In addition, Jurassic white limestones (most probably *Vidraço* type), with typical conchoidal fracture, coming from the Estremadura Calcareous Massif (about 120 km NW of Évora) have been distinguished in the fortifications. These rocks are normally employed in the construction of pedestrian crossings in the historic center and are often applied in recent restoration and expansion works in other monuments of the city (LOPES, 2019).

In short, the materials used for the construction of the fortification perimeter are largely of local origin although rocks coming from different areas have been detected.

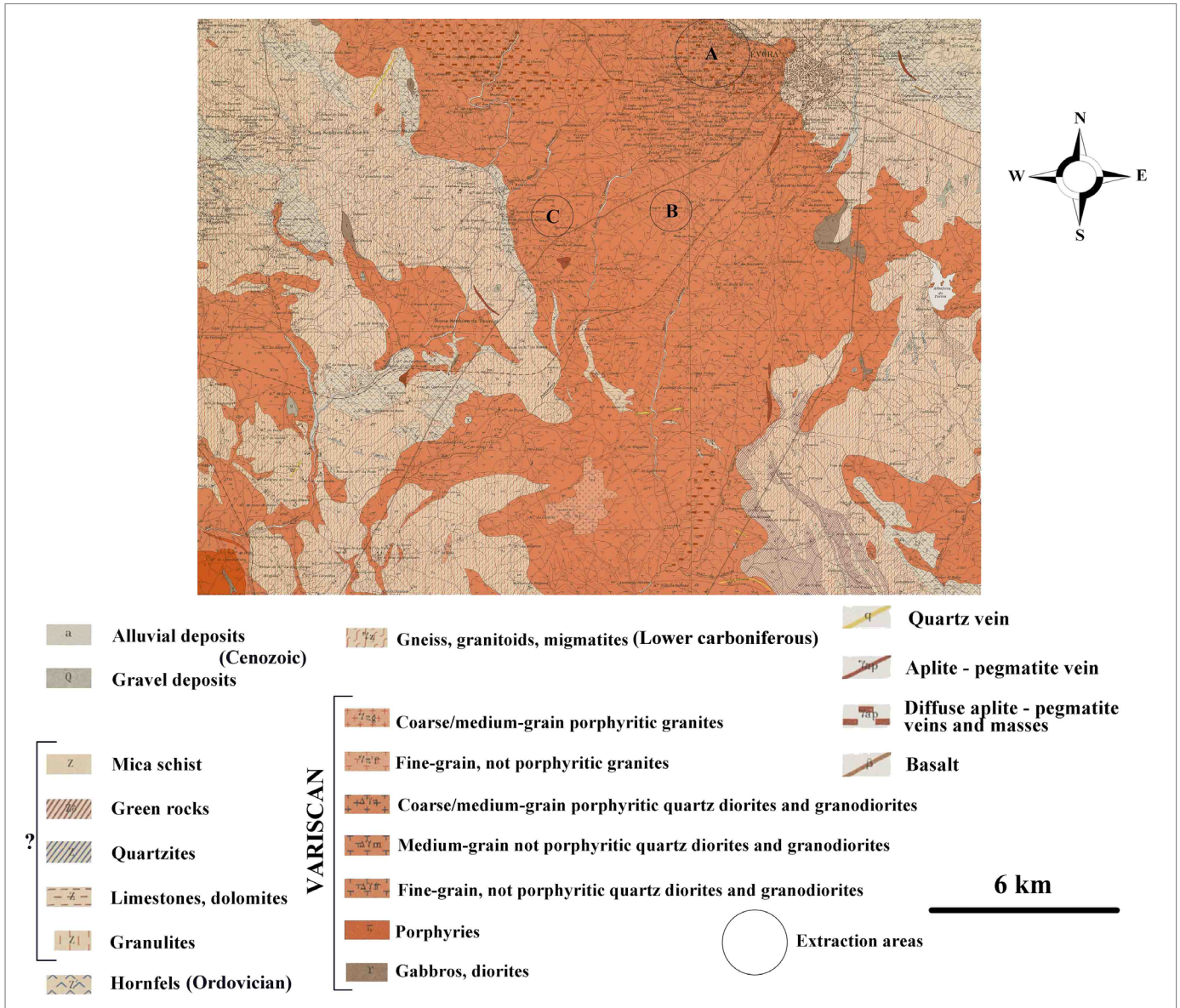


Fig. 3. Extract of the Geological Map of Portugal, scale 1:50000, Évora (Sheet 40A), Direção Geral de Minas e Serviços Geológicos de Portugal, 1969, modified. A. São Bento extractive area; B. Monte das Flores extractive area; C. Valverde extractive area.

Fig. 3. Extrato da Carta Geológica de Portugal, na escala 1:50000, Évora (Folha 40A), Direção Geral de Minas e Serviços Geológicos de Portugal, 1969, modificado. A. Zona extractiva de São Bento; B. Zona extractiva de Monte das Flores; C. Zona extractiva de Valverde.

According to the information obtained by consulting local population, the extraction sites for the fortification's lithologies could be different. Three main mining areas would have been identified in the surroundings of the city – São Bento, Monte das Flores and Valverde – indicated, respectively, in Fig. 3 as A, B and C circles.

The São Bento area (NW Évora, coordinates 38°34'50.70" N - 7°56'15.67" O) consists of a granitic elevation composed of various quarries with different dimensions. The widest are in the west side of the plateau while on the east side there are small quarries and widespread "extraction samples" of small dimensions. Based on local evidence, the quarries to the west of the plateau would have been activated during the 20th century but are now abandoned. Historical evidence demonstrates the probable presence at the São Bento of mining activities dating back to the Roman period (LOPES, 2020).

The technique of exploration commonly employed during this period involved making incisions along the edges of the outcrop, into which dried wood pieces were inserted. Water was added to the dry wood causing it to swell and thus break the rock (LOPES *et al.*, 2000).

Given the abundance of quarries in São Bento area and given its proximity to the city, most of the granitoid rocks as well as the aplites, pegmatites and migmatites used for the construction of the wall would most likely come from this site.

Monte das Flores (SW Évora, coordinates 38°31'47.91" N - 7°57'34.53" O) is known for the presence of a currently active extraction site of granitoids for aggregate purpose. However, in the same B area, traces of extraction dating back to the Roman or Medieval period were discovered (LOPES, 2020). There are no signs of ancient quarries, or they have not been identified yet, in the Valverde area (C area) (SW Évora, coordinates 38°31'37.29" N - 8° 0'1.59" O). Currently here, there are two "recent" quarries, and only one is active. As regards the supply of the other rocks ascertained on the fortifications (e.g., hornfels, gabbros and diorites), it is hypothesized there were no real quarries but that boulders were collected from the surroundings of the city.

Regarding the marbles, it is probable they are spoliation materials from demolished monuments, as frequently recorded by other studies (COLUMBU *et al.*, 2018; KINNEY, 2013).

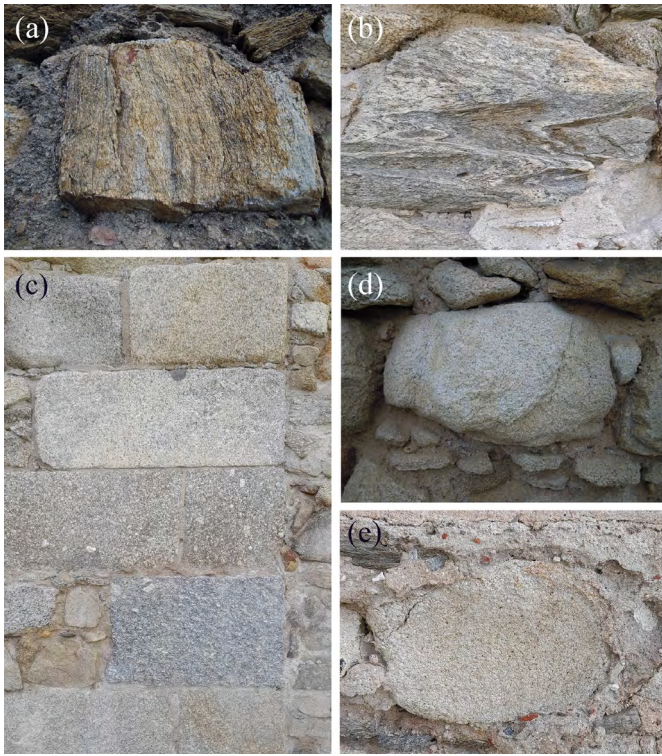


Fig. 4. Lithologies found in the Cerca Nova fortifications: (a) gneiss; (b) migmatite; (c) different granitoids of hercynic age; (d, e) equigranular leucogranites strongly affected by weathering.

Fig. 4. Litologias encontradas nas fortificações de Cerca Nova: (a) gnaíse; (b) migmatito; (c) diferentes granitóides de idade hercínica; (d, e) leucogranitos equigranulares fortemente alterados.

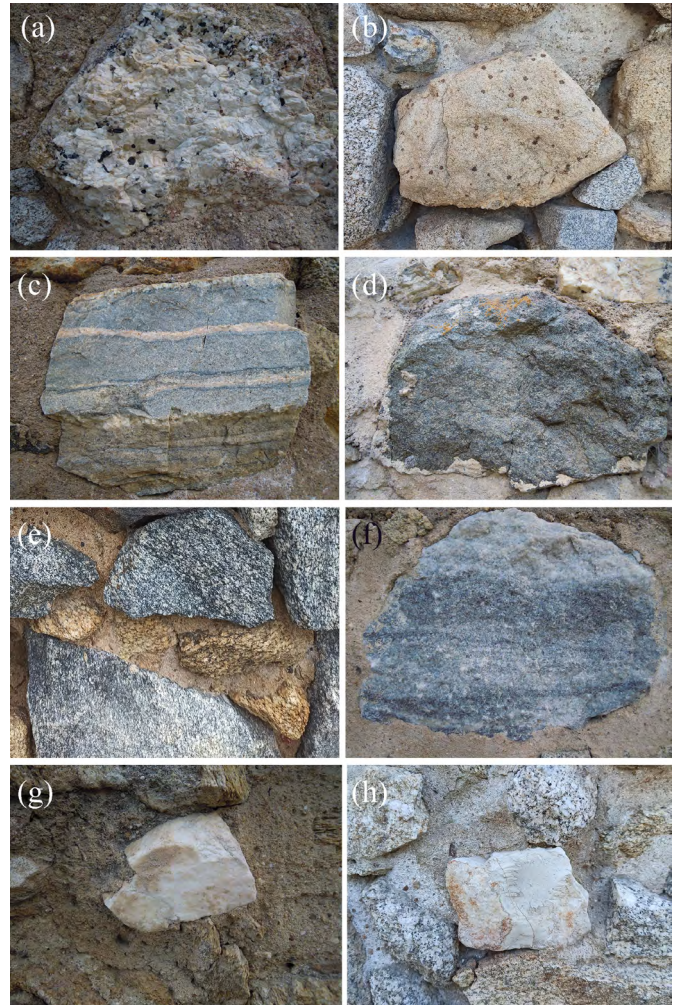


Fig. 5. Lithologies found in the Cerca Nova fortifications: (a) pegmatite; (b) aplite; (c) hornfel; (d) gabbro; (e) irregular ashlars of diorites; (f) *Trigaches-São Brissos* marble; (g) probably *Estremoz-anticline* marble; (h) limestone (most probably *Vidraço* type).

Fig. 5. Litologias encontradas nas fortificações da Cerca Nova: (a) pegmatito; (b) aplito; (c) hornfel; (d) gabro; (e) silhares irregulares de dioritos; (f) mármore de *Trigaches-São Brissos*; (g) provavelmente mármore do anticlinal de Estremoz; (h) calcário (muito provavelmente de tipo *Vidraço*).

4.2 Vascular flora characterization

The plant density on the wall usually varies from zero or less than one up to *ca.* 40 individuals per m². The greatest density is registered in its southern side. The most common plants shown in the inventory of vascular flora (Fig. 6) are distributed in all portions of the wall. Other plants are located in precise positions, close to individuals of the same species found nearby and often used as ornamental plants. A typical example is the *Salvia rosmarinus* L., located exclusively in a SW portion of the wall, where a roadside flowerbed of the same species is located. Other cases of plants located only in determinate position of Cerca Nova, include the *Oxalis corniculata* L., *Ageratina Adenophora* Spreng., *Wigandia Urens* Kunth, and *Eucalyptus camaldulensis* Dehnh. As reported by Fig. 6, the most frequent vascular flora refers to the *Parietaria* L. genus (61,8 %), followed by *Adiantum* L. (16,3 %) and *Mercurialis* L. (7,9 %).

Generally, the analyzed sample of vascular flora at Cerca Nova fortifications reaches 42 taxa, of which 50% are native and 50% are exotic. Some examples of detected species are present in Fig. 7 and Fig. 8. In the analysed sample, a total of 26 families and 34 genera have been recognised.

The invasive status at local level has been awarded according to the current legislation in force in Portugal – Decree-Law n° 92/2019 for

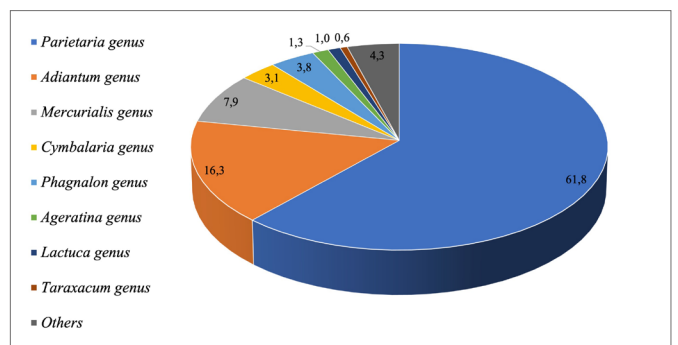


Fig. 6. Percentage of vascular plant species per genus across Cerca Nova fortifications.
Fig. 6. Percentagem das espécies de flora vascular por género nas fortificações da Cerca Nova.

Mainland and Madeira and Regional Legislative Decree n° 15/2012/A for Azores, that lists more than 200 plant species as invasive.

On the fortifications, nine species have been recognized as invasive in whole Portugal. Six of them – *Ageratina Adenophora* Spreng., *Erigeron karvinskianus* DC., *Erigeron canadensis* Ten., *Amaranthus blitum* L., *Ailanthus altissima* Mill. and *Robinia pseudoacacia* L. – are considered invasive only in Continental Portugal. The other three, namely *Oxalis cor-*



Fig. 7. Some examples of native plants observed on the fortifications. (a) *Parietaria judaica* L.; (b) *Sedum album* L.; (c) *Lactuca serriola* L.; (d) *Sonchus oleraceus* L.; (e) probably *Lavatera cretica* L.; (f) *Adiantum capillus-veneris* L.; (g) *Phagnalon saxatile* L.; (h) *Salvia rosmarinus* L.

Fig. 7. Alguns exemplos de plantas nativas observadas na muralha. (a) *Parietaria judaica* L.; (b) *Sedum album* L.; (c) *Lactuca serriola* L.; (d) *Sonchus oleraceus* L.; (e) provavelmente *Lavatera cretica* L.; (f) *Adiantum capillus-veneris* L.; (g) *Phagnalon saxatile* L.; (h) *Salvia rosmarinus* L.

niculata L., *Adiantum hispidulum* Sw. and *Acanthus mollis* L. are classified as invasive in the Autonomous Region of Madeira.

Ailanthus altissima was firstly introduced to Europe by the French missionary Pierre d'Incaville, more than 260 years ago, who sent seeds from Nanking to Paris (FERET, 1985). *Ailanthus altissima* has spread in Portugal and over Europe, where in many countries is under invasiveness status. As regards to *Ageratina Adenophora* in Portugal, documented studies attest its introduction at Madeira and Azores, in 1840 and 1894, respectively (SEEBENS *et al.*, 2017).

As regards *Erigeron canadensis*, there is no precise bibliographical information about the dynamics of its introduction into Europe. In any case, another species of *Erigeron* (e.g. *E. floribundus*) was reported in central Portugal already between 1961 and 1970 (LIENDO *et al.*, 2021).

The biological spectrum of the native flora reveals that chamaephytes are the most represented (7 taxa, 33%), followed by hemicryptophytes (6 taxa, 29%), phanerophytes (3 taxa, 14%), therophytes (4 taxa, 19%) and geophytes (1 taxa, 5%).

The exotic plants are mostly characterized by phanerophytes (10 taxa, 48%), followed by hemicryptophytes (4 taxa, 19%), therophytes (4 taxa, 19%) and chamaephytes (3 taxa, 14%).



Fig. 8. Some examples of exotic plants observed on the fortification. (a) *Wigandia urens* Kunth, *Ficus carica* L.; (c) *Oxalis corniculata* L.; (d) probably *Casuarina equisetifolia* L.; (e) *Ailanthus altissima* Mill.; (f) probably *Ulmus pumila* L.; (g) *Ageratina adenophora* Spreng; (h) *Robinia pseudoacacia* L.

Fig. 8. Alguns exemplos de plantas exóticas observadas na muralha. (a) *Wigandia urens* Kunth, *Ficus carica* L.; (c) *Oxalis corniculata* L.; (d) provavelmente *Casuarina equisetifolia* L.; (e) *Ailanthus altissima* Mill.; (f) provavelmente *Ulmus pumila* L.; (g) *Ageratina adenophora* Spreng; (h) *Robinia pseudoacacia* L.

Regarding the geographical origin of non-native taxa (Fig. 9), the major source is represented by the tropical American (19,5%), followed by Mediterranean and African component (17,1% both), Australian (9,8 %) and Central Asia (9,8%).

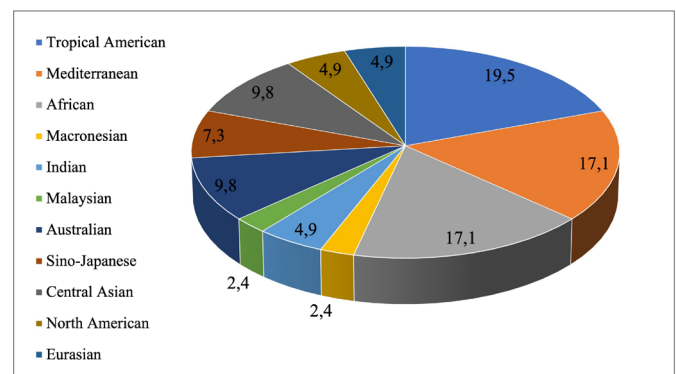


Fig. 9. Percentages of non-native vascular flora observed on Cerca Nova fortifications, by bio-geographical region.

Fig. 9. Percentagem da flora vascular não nativa observada nas fortificações da Cerca Nova, por região biogeográfica.

5. Conclusions

The analysis of the Évora's Cerca Nova fortifications has demonstrated the presence of various rock materials coming mainly from local quarries (e.g. São Bento) and the probable use of scattered boulders collected from the nearby countryside. This is typical of vernacular architecture of the medieval period. Some of the quarries present at São Bento (A area) or Monte das Flores (B area) were active until recent times and show extractive signs of previous historical periods. As often happens in similar cases, it is probable that in the quarries the mining activity began in the past and then continued in the contemporary age. Some rock fragments found in the masonry are unrelated to the geology of the city's surroundings (e.g., marbles) and they probably are the results of spoliations.

As regards the presence of vascular plants on the fortifications, it is notable that 50% of the 42 identified taxa are non-native. Between them, 9 taxa are under invasiveness status (6 in Continental Portugal and 3 in

Madeira island). It is important to note, however, that in the sample of plants, invasive individuals represent only 2,4 %. The origin of the non-native taxa is mainly from the tropical American biogeographical region.

This work appears to be the first to simultaneously address materials and provenance while also providing data on the presence of higher plants on the Évora wall. Although this approach is well-established in the literature, this paper uniquely applies it to a UNESCO monument.

The research is expected to progress further. Recently, the Évora Wall was chosen as a study monument in the INTERREG Portugal-Spain HEPERSTONE project (code 0274_HEPERSTONE_4_E_V4). In this phase, data will be collected on the wall's exposure to natural and anthropogenic risks. A portion of the project will focus on characterizing invasive flora and calculating risk indexes.

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