# *Excavated monuments as environment for plants Conimbriga, Portugal: a study case*

Teresa M.L.S. Mouga, Maria Teresa F. Almeida
*Departamento de Botânica, Faculdade de Ciências e Tecnologia, Universidade de Coimbra, 3049 Coimbra, Portugal*

**Abstract**

This paper deals with weathering provoked by higher plants on excavated and non excavated archaeological sites. Floristical survey of the Roman town Conímbriga, Portugal, is going on for more than 3 years.

The plant cover on excavated and non excavated sites are different. In the non excavated sites, the plant succession drifts towards the natural Mediterranean plant cover.

In the overground-excavated sites the plant cover is mainly represented by typical wall vegetation, along with Mediterranean species.

The weathering caused by the higher plants on excavated sites is highly damaging to the monuments as plants treat them as natural substrata from where they extract all they needs, and exude all their products.

**Keywords**

Higher-plants, vegetation, biodeterioration, monuments.

## Introduction

Conímbriga is a roman town, situated 17 km from Coimbra, in the centre part of Portugal. This town was prosperous from the 1st to the 5th Century AD. The terror of the Sueves invasion made wealthy people abandon the place. Slowly the town died away. On the end of the 19th century excavations started. Since then important buildings of the town have been excavated. Until the 50's the area was normally cultivated of which some traces can still be found, specially on cultivars. Nowadays the vegetation of the non excavated locals are progressively becoming similar to the natural vegetation of the area. The natural vegetation of the area is typically Mediterranean, and is located in the Meso-Mediterranean province, according to the classification of Rivaz-Martínez. Simultaneously vegetation is growing on the excavated monuments: walls, columns, gardens, main-wall, pools, etc.. So monuments are acting like environment for plants. Likely as in the natural environment, on monuments we observe a succession of plants (spatial and temporal). Initially, in the early stages of colonisation, we find mainly minute annual ruderal plants. The end of the succession is represented by shrubby vegetation, similar to the surrounding vegetation. The type of vegetation and its succession is influenced by the substrata, the micro-climate (namely humidity, temperature, exposition, ...), the anthropic influence and the age of the excavation.

The growing of the vegetation causes severe problems to the conservation of the ruins for it is not only anaesthethical, but it causes deterioration of the substrata. Although the primary deteriogens of the monuments are micro-organisms, algae, fungi and lichens, all the aspects concerning the interaction between vascular plants and monuments can not be ignored. They are there and they are damaging!

## General characteristics of Conímbriga

*Geographical situation*

Conímbriga is located in the Centre region of Portugal, in the "Limestone Western Centre of Portugal" (Amaral Franco, J., 1973-1974), in the Mediterranean region (Fig. 1).

Conímbriga was built on a roughly triangular plateau, on to sides of which are abrupt walls. The plateau reaches a height of about 100 meters (ranging from 101,9 m to 109,2 m).

*Climatic characteristics*

As we can see in Fig. 2, Coimbra and this region of Portugal has a hot dry summer, and a fairly cold wet winter (hardly reaching negative temperatures):

*Geology*

The plateau is formed by Dogger limestone and, on the

top of it, reaching the surface, there is calcareous tuft in a layer up to 30 meters. These rocks have a quaternary origin.

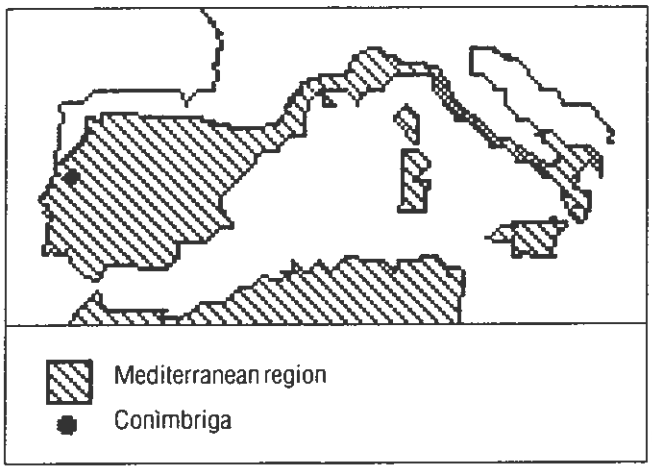


*Fig. 1 - Mediterranean region of Western Europe (adapted from Rivas-Martínez, S., 1987).*

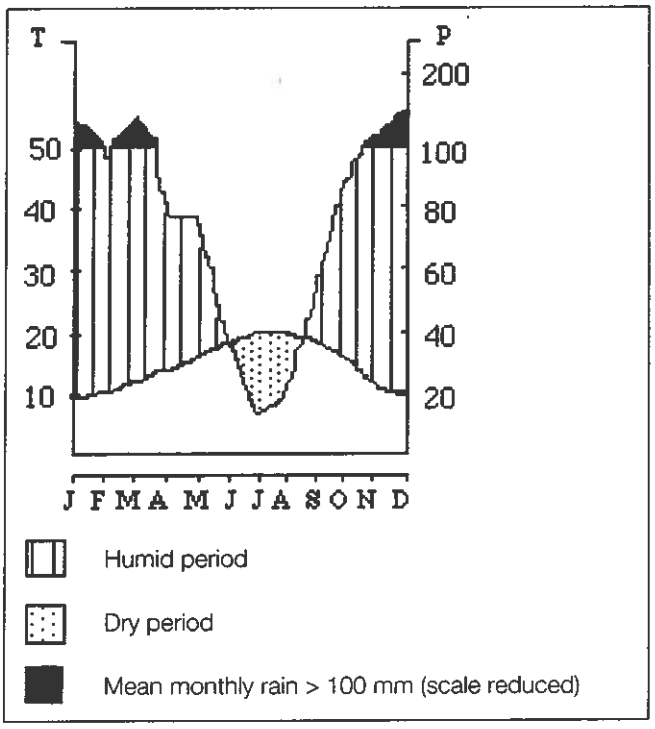


*Fig. 2 - Climatic diagram of Coimbra. According to Rivas - Martinez, S., Coimbra has a Meso-Mediterraneah Sub-Humid Climte. (Rivas-Martinez, S., 1981)*

| | | |
|---|---|---|
| COIMBRA | T | 15,9 o C |
| 141 m above see level | P | 961 mm |
| 30 years survey | | |

Since calcareous rocks were the most available in the area these are the main construction materials of the city. Yet, other types of limestone, marble, sandstone, glass, tile, and other materials can be found in Conímbriga.

## General characteristics of the vegetation

The plateau of Conímbriga is only partly excavated (c. 1/6) and open to public access. The other 5/6 are not open to the public and vegetation grows freely, except for an occasional cut, specially in the summer time. Phytosociological surveys are being made for 3 years, according to the method of Braun-Blanquet, both on the "wild" part of the plateau and on the ruins.

270 different species were found, some only growing the unexcavated part, some only on the ruins and some were found to grow both on soil and stone (Table I).

| | N.Sps | % |
|---|---|---|
| PLATEAU | 135 | 50,00% |
| WALLS | 32 | 11,85% |
| BOTH | 103 | 38,15% |
| TOTAL | 270 | |

*Table I - number and percentage of species surveyed in the plateau of Conímbriga.*

The plateau was cultivated until the 50's, particularly with olive trees, and so the actual cover of vegetation is quite young. Among the 238 species that grow on the plateau the herbaceous plants, Therophytes and Hemicriptophytes, are predominant (47,41% and 33,33% respectively). Similar percentages were found of the plants growing on the ruins (Table II). The Therophytes are always the most abundant.

The origin of the vegetation is mainly Mediterranean (more than 50%), both for the vegetation of the soil and that of the ruins (Table III).

## Weathering ability of higher plants

*Mechanical action:*

The roots of higher plants weaken the walls by their infiltration into the structure. Larger plants, having larger and stronger roots are obviously more harming.

The roots of higher plants usually grow in areas of less

| LIFE FORM | PLATEAU | | WALLS | | BOTH | | TOTAL | |
|---|---|---|---|---|---|---|---|---|
| | N.Sps | % | N.Sps | % | N.Sps | % | N.Sps | % |
| TEROPHYTES | 64 | 47,41% | 14 | 43,75% | 47 | 45,63% | 125 | 46,30% |
| HEMICRIPTPHYTES | 45 | 33,33% | 9 | 28,13% | 29 | 28,16% | 83 | 30,74% |
| GEOPHYTES | 18 | 13,33% | 3 | 9,38% | 9 | 8,74% | 30 | 11,11% |
| CHAMAEOPHYTES | 3 | 2,22% | 4 | 12,50% | 6 | 5,83% | 13 | 4,81% |
| NANOFANEROPHYTES | 4 | 2,96% | 0 | 0,00% | 3 | 2,91% | 7 | 2,59% |
| PHANEROPHYTES | 1 | 0,74% | 2 | 6,25% | 9 | 8,74% | 12 | 4,44% |
| TOTAL | 135 | | 32 | | 103 | | 270 | |

*Table II - Number and percentage of species, according to Raukier's life form:*
*Terophytes - annual*
*Hemicriptophytes - herbaceous perennial*
*Geophytes - herbaceous; perennial buds below the surface*
*Chamaeophytes - woody or herbaceous; perennial buds up to 25 cm above soil level*
*Nanophanerophytes - shrubs; perennial buds between 25 cm and 2 m above soil level*
*Phanerophytes - trees or shrubs; perennial buds higher than 2m above soil level*

| COROLOGY | PLATEAU | | WALLS | | BOTH | | TOTAL | |
|---|---|---|---|---|---|---|---|---|
| | N.Sps | % | N.Sps | % | N.Sps | % | N.Sps | % |
| COSMOPOLITE | 13 | 9,63% | 1 | 3,13% | 5 | 4,85% | 19 | 7,08% |
| SUB COSMOPOLITE | 15 | 11,11% | 2 | 6,25% | 10 | 9,71% | 27 | 10,06% |
| EURASIATIC | 11 | 8,15% | 3 | 9,38% | 18 | 17,48% | 32 | 11,92% |
| PANTROPICAL | 1 | 0,74% | 2 | 6,25% | 4 | 3,88% | 7 | 2,62% |
| CIRCUMBOREAL | 5 | 3,70% | 2 | 6,25% | 3 | 2,91% | 10 | 3,74% |
| IBERIAN PENINSULA | 12 | 8,89% | 0 | 0,00% | 2 | 1,94% | 14 | 5,22% |
| ATLANTIC | 4 | 2,96% | 2 | 6,25% | 2 | 1,94% | 8 | 3,00% |
| AFRICA | 0 | 0,00% | 0 | 0,00% | 1 | 0,97% | 1 | 0,37% |
| MEDITERRANEAN | 74 | 54,81% | 20 | 62,50% | 58 | 56,31% | 153 | 56,73% |
| TOTAL | 135 | | 32 | | 103 | | 270 | |

*Table III - Number and percentage of species according to their origin (corology):*
*Cosmopolite - species that grows all over the world*
*Sub cosmopolite - species that grows almost in all world but an important area is missing (a continent or a climatic area)*
*Eurasiatic - species that grows in the eurasiatic continent*
*Pantropical - species that grows in all the tropical area of Eurasia, Africa and America*
*Circumborial - cold / temperate area of Eurasia and North America; high mountain*
*Iberian Peninsula - endemic species*
*Atlantic - species that grows on the littoral belt of the Atlantic cost of Europe*
*Africa - species originary of the African continent*
*Mediterranean - species that grows in the Mediterranean area (Fig. I).*

resistance. They colonise cracks and crevices that are then enlarged by their mechanical strength and new cracks and crevices are formed (Caneva, G., Altieri, A., 1988; Domaslowski, W., 1982; Riederer, J., 1981; Winkler, E.M., 1975).

*Chemical action:*

The roots have strong negative charge, that combined with the positive hydrogen ions of the rhizosfere causes a large amount of chemical reactions which significantly weather the mineral surfaces (Keller, W.D.,

Frederickson, A.F., 1952).

Higher plants exudate several substances particularly through roots. The most damaging are organic acids (Caneva, G., Altieri, A., 1988). Organic acids have a chelating ability, which means that they are able to withdraw a metal cation from the mineral, to which thus strongly link. The removal of this cation causes the dissolution of the mineral (Boyle, J.R., Voigt, G.K., Sawhney, B.L., 1974).The exudates are essential for the survival of the plant, for they release the needed nutrient ions from the mineral surfaces.

*Humidity:*

Higher plants can also cause alterations in the micro environment were they grow. Where they grow a permanent humidity and shade on the surface of the stone is increased. This creates a microenvironment that favours weathering of stone by other deteriogens (Allsopp, D., Drayton, I.D.R., 1975; Fisher, G.G., 1972).

## Walls as substrata for higher plants

The ruins of Conímbriga are a very favourable place for the growth of higher plants because:

1 Conímbriga is in a rural area. Most of the involving area is of agricultural fields and there is also a natural wood. The pollution is low in spite of the presence of factories some kilometres to the Southeast. The danger of pollution weathering is not in question here. A huge diversity of plants can be found due to intensive agriculture and invasion of natural vegetation. Some species growing on the walls are typical of Mediterranean woods (maquis): *Pistacia lentiscus* L., *Laurus nobilis* L., *Rhamnus alaternus* L., *Jasminum fruticans* L., *Daphne gnidium* L. , *Osyris alba* L. and *Smilax aspera* L.. All these are woody plants (Nanophanerophytes or Phanerophytes) that cause large mechanical damage by root penetration of the walls.
2 The orientation of the ruins is also important. Microclimatic factors influence both the weathering by rain, wind, etc., and the establishment of plant communities. Different number of individuals and different species associations grow depending on the orientation of the wall.
3 The main construction material of the ruins is limestone. The carbonate minerals that compose the limestone are easily weathered by either inorganic or organic phenomena. Higher plants exude organic acids through their roots, and the presence of any acid attacks the mineral structure. This process begins with the approach of a Hydrogen ion from the acid to a CO3 group from the calcite ($CaCO_3$).In consequence of this approach, the H-ion links to the $CO_3$ group and thus releasing the Calcium ion, and weathering the material.
4 Several species of ruderal plants such as *Taraxacum officinale* Weber, appear on disturbed ground, following the anthropic action.
5 The age of the excavations is important because the longest the exposition to rain, wind and other climatic factors, the larger the damage to the structures.
6 Most of the main-wall has been always overground. It was used as an ordinary wall to establish the limits of the agricultural fields. So the main wall is in a severe state of degradation, and part of it has already fallen.

Thus, Conímbriga is a mixed environment: not antropogenic, not natural , but somewhere in between. We find Mediterranean vegetation growing on the ground, mixed with antropogenic vegetation. Some of these species were able to colonise the walls, along with the typical wall vegetation.

| | EXCAVATED | | MAIN-WALL | | SOIL OF RUINS | |
|---|---|---|---|---|---|---|
| LIFE FORM | mean Sps | % | mean Sps | % | mean Sps | % |
| TEROPHYT | 8,95 | 61,59 | 6,00 | 34,80 | 12,33 | 60,16 |
| HEMICRIPTOPHYT | 1,79 | 12,32 | 3,65 | 21,15 | 2,33 | 11,38 |
| GEOPHYT | 0,42 | 2,90 | 0,94 | 5,46 | 1,67 | 8,13 |
| CAMEPHYT | 3,26 | 22,46 | 4,29 | 24,91 | 3,83 | 18,70 |
| NANOPHANEROPHYT | 0,00 | 0,00 | 0,76 | 4,44 | 0,17 | 0,81 |
| PHANEROPHYT | 0,11 | 0,72 | 1,59 | 9,21 | 0,17 | 0,81 |
| TOTAL | 14,53 | | 17,24 | | 20,50 | |

*Table IV - Mean values for number of species and percentages on three zones of the ruins:*
*Thermae (Excavated) - vertical or horizontal walls, 19 surveys*
*Main-wall - vertical or horizontal walls, 17 surveys*
*Domus of Cantaber (Soil of ruins) - soil that covers the floor, 6 surveys*

## Discussion

Several types of vegetation can be found in Conímbriga, associated with the different conditions mentioned. There is a predominance of the Therophytes, but different percentage in each zone (Table IV):

- *Thermae*

The most abundant species are:

| | |
|---|---|
| Sedum album L. | C |
| Vulpia muralis (Kunth) Nees | T |
| Micromeria juliana (L.) Reichemb. | C |
| Campanula erinus L. | T |
| Desmazeria rigida (L.) Tutin | C |
| Lophochloa cristata (L.) Hyl. | C |
| Sedum rubens L. | C |
| Saxifraga granulata L. | T |
| Medicago minima (L.) Bartal | T |
| Sagina apetala L. | T |
| Linaria supina (L.) Chaz. | C |
| Crepis capillaris (L.) Wallr. | T |
| Sonchus oleraceus L. | T |
| Geranium rotundifolium L. | T |

Other characteristics of the vegetation:
Lowest number of species per m2 = 14,53.
Total number of species = 48.
High percentage of Therophytes (>60%).
High percentage of seedlings growing on the beginning of the winter, dying when the weather gets dryer and hotter.
Medium height of vegetation - c. 15 cm.
Very young vegetation.
LIFE FORM
T (Therophytes) = 57,1429%
C (Camephytes) = 42,8571%

- *Main-wall*

The most abundant species are:

| | |
|---|---|
| Micromeria juliana (L.) Reichemb. | C |
| Sedum album L. | C |
| Anthirrhinum majus L. | C |
| Parietaria diffusa L. | H |
| Hyparrhenia hirta (L.) Stapf | H |
| Ruta chalepensis L. | C |
| Linaria supina (L.) Chaz. | C |
| Campanula erinus L. | T |
| Desmazeria rigida (L.) Tutin | T |
| Rubia peregrina L. | P |
| Rubus ulmifolius Schott | NP |
| Muscari comosum (L.) Miller | G |
| Dactylis glomerata L. | H |
| Ceterach officinarum Willd. | H |

Other characteristics of the vegetation:
Medium number of species per m2 = 17,24
Largest number of species = 65
High percentage of perennial and woody plants = 65,17%
Large number of woody species, reaching a medium height of c. 40 cm.
More mature vegetation.
LIFE FORM
T (Therophytes) = 14,2857%
H (Hemycriptophytes) = 28,5714%
G (Geophytes) = 7,14286%
C (Chamaeophytes) = 35,7143%
NP (Nanophanerophytes) = 7,14286%
P (Phanerophyphytes) = 7,14286%

- *Domus of Cantaber:*

The most abundant species are:

| | |
|---|---|
| Micromeria juliana (L.) Reichemb. | C |
| Cynodon dactylon Richard | G |
| Linaria supina (L.) Chaz. | C |
| Medicago minima (L.) Bartal | T |
| Sedum album L. | C |
| Campanula erinus L. | T |
| Blackstonia perfoliata (L.) Hudson | T |
| Conyza canadensis L. | T |
| Sonchus oleraceus L. | T |
| Vulpia muralis (Kunth) Nees | T |
| Anthirrhinum majus L. | C |
| Anagallis arvensis L. | H |
| Hypericum perforatum L. | H |
| Parietaria diffusa L. | H |

Other characteristics of the vegetation:
Largest number of species per m2 = 20,50
Number of species = 48
Large number of Therophytes, but lower than in the Thermae.
Medium height of vegetation c. 20 cm.
Large number of seedlings, but the vegetation is not so young as in the Thermae.
LIFE FORM
T (Therophytes) = 42,8571%
H (Hemycriptophytes) = 21,4286%
G (Geophytes) = 7,14286%
C (Chamaeophytes) = 28,5714%

## Conclusions

1 The universal number of Therophytes in Conímbriga is an indicator of the youth of the vegetation. The vegetation both on the plateau and on the ruins is in inicial state of succession and will evolve to the climax vegetation: probably the characteristic Mediterranean

vegetation that grows on the natural wood nearby. Already most of the species are of Mediterranean origin, in spite of the youth of the vegetation.

2 Several steps of the evolution of the vegetation that grows on the ruins can be seen in Conímbriga; the youngest being the Thermae, followed by the Do*mus* of Cantaber, and the most evolved on the Main-wall.

3 Each step is characterised by a number of associated species. Each group of species grows according to the edafic and climatic condition it finds. The better preserved ruins are harder to colonise, thus the number of species able to survive is low. They are mainly Therophytes (Thermae), the less demanding when nutrients are concerned. However, they only survive a few months. Most of the plants die when the weather gets hotter and dryer.

4 - A different type of vegetation grows in horizontal areas such as the floor of the Do*mus* of Cantaber. This area is the only one open to the public and the vegetation is periodically cut. With the large accumulation of organic matter, the vegetation finds better conditions then in the Thermae, growing faster.

5 The Main-wall was always aboveground. It was permanently exposed to deterioration by climatic factors and biodeterioration by micro and macro-organisms. The type of vegetation growing on the main-wall is an indicator of its weathered condition. A large number of both woody species and typical Mediterranean (maquis) vegetation is growing on the main-wall, increasing dramatically the rate of weathering.

6 The Therophytes are not too damaging to structures for they are all small annual plants with small root systems. These roots are not very long and thus do not grow very deep into the structure. Furthermore, since the plants are small, they do not have large mineral needs so they will not need to extract so many nutrients from the substrata.

As the number of other life forms increase, the damage also increases. The plants get larger, the root systems penetrate deeper into the structure and they exudate more harming substances, thus causing larger damage to the ruins.

7 Several species of plants grow in every wall of Conímbriga:

*Micromeria juliana (L.) Reichemb.*
*Sedum album L.*
*Campanula erinus L.*
*Linaria supina (L.) Chaz.*

A group of vegetation can be defined by these species as 'wall vegetation'.

## Acknowledges

This project is being supported by J.N.I.C.T. (Junta Nacional de Investigação Científica e Tecnológica.-Portugal). Thanks are dued to the Monographical Museum of Conímbriga.

## References

Allsopp, D.and Drayton, I.D.R. (1975) The higher plants as deteriogens, in Proceedings of the Third International Biodegradation Symposium (eds. Sharpley, J.M. and A. M. Kaplan), London, pp. 357-364.

Amaral-Franco, J. (1973-1974) Predominant Phytogeographical zones in continental Portugal. Bol. Sociedade Broteriana, 47, 2nd series, suppl., 91-102.

Boyle, J.R., Voigt, G.K. and Sawhney, B.L. (1974) Chemical weathering of biotite by organic acids. Soil Science, 117, 42-45.

Braun-Blaquet, J. (1979) Fitosociologia. H. Blume Ediciones, Madrid.

Caneva, G.and Altieri, A. (1988) Biochemical mechanisms of stone weathering induced by plant growth, in Proceedings of the 6th International Congress on Deterioration and Conservation of Stone, Torun, pp. 32-44.

Domaslowski, W. (1982) La Conservation Préventive de la Pierre. UNESCO, Paris.

Graham, E.R. (1941) Colloidal organic acids as factors in the weathering of anorthite Soil Science, 52, 291-295.

Fisher, G. G. (1972) Weed damage to materials and structures. Int. Biodet. Bull., 8, 101-103.

Keller, W.D. and Frederickson, A.F. (1952) Role of plants and colloidal acids in the mechanism of weathering. Am. Journal of Science, 250, 594-608.

Riederer, J. (1981) The conservation of historical monuments in Sri Lanka Pre-prints to the International Symposium "The conservation of stone II", Vol. II, Bologna, pp. 737-755.

Rivas- Martínez, S. (1981) Les Étages bioclimatiques de la végétation de la Péninsule Ibérique. Accts III Congr. OPTIMA, An. Jard. Bot. Madrid, 37(2), 251-268.

Rivas-Martínez, S. (1987) Introduccion: Nociones sobre Fitosociologia, Biogeografia y Bioclimatologia, in La vegetacion de España (eds. Lorca, M.P., Rivas- Martínez, S. ) Coleccion Aula Aberta, Universidad de Alcalá, Servicio de Publicaciones, Madrid, pp. 19-45.

Winkler, E.M. (1975) Stone decay by plants and animals, in Stone: Properties, Durability in Man's Environment, 2nd revised edition, Springer -Verlag, Wien, pp. 154-161.