Biodeterioration of Polychrome Roman Mosaics

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ABSTRACT

The mosaics from the Roman remains of Italica, which was founded in 206 BC near present-day Seville, are threatened by the ravages of nature that are destroying these masterpieces from the second century AD. Since the beginning of this century, the exposure of most of the mosaics after excavation has resulted in colonization by pioneering species of lichens and mosses, as well as by subsequent allied plants. The ultimate effect is the complete destruction of the mosaics, with some unfortunate examples being recorded.

INTRODUCTION

A total of 133 pavements have been found in Italica. They have been catalogued as 111 *opus tesellatum* (pavement formed by various coloured cubic tesserae), 7 *opus sectile* (pavement constructed with flagstones of different geometric forms), 8 *opus fliginum* (pavement made of cubic terracotta pieces). 2 *opus segmentatum* (pavement distinguished from *opus sectile* by the thinness of the flagstones). 4 *opus signinum* (old pavement made of lime and pieces of broken ceramics in which tesserae were inserted at certain distances to form simple geometric designs) and 1 *opus spicatum* (pavement in which the tesserae are substituted by small brick pieces placed on their cut edges, in such a manner that they reproduce spike or fish-bone forms). Most of them belong to the second century AD. Several of the mosaics have been deposited in a museum, private houses, and archaeological stores, and four have disappeared. Other mosaics are at present covered with sand for conservation purposes.

However, there is still the possibility of studying a large number of mosaics in Italica. In this survey, we have selected two representative mosaics: the Labyrinth, a polychrome mosaic located in the so-called House of Neptune's Mosaic, a relatively simple case in which there are four basic types of stony tesserae, and Tellus, a polychrome mosaic from the House of the Birds, with a wide variety of stony, vitreous and ceramic tesserae. Therefore, the types of tesserae considered in this work are stony: grey, white, orange, pink and red; ceramic: brown; and vitreous: with different tones of red, orange, blue and green. These colours were usually obtained by the Romans by addition of different metallic oxides to the vitreous paste (Fiorentini Roncuzzi, 1984).

This paper presents a study of the colonization and attack of the different tesserae and mortars from two representative mosaics by lichens, mosses, and vascular plants.

THE MOSAICS

Italica was founded by General Scipio the African in the year 206 BC, following the battle of Ilipa against the Carthaginians in the final phase of the Second Punic War. During the second century, the emperor Hadrian greatly contributed to the development of his birthplace city, converting it into the first monumental city of Hispania. After a period of splendour which lasted throughout the third and fourth centuries, the city began to decline, until it was finally abandoned and sacked during the following centuries.

Excavation of Italica began in the eighteenth century, but did not advance much until the middle of the nineteenth. The mosaics conserved in Italica are those excavated from 1919, with a very active period between 1924 and 1932, during which were excavated the houses shown today.

The excavated Archaeological Site of Italica is formed by a number of public buildings and nine houses. Perimeters bounded by walls of bricks cemented with lime mortar separate the different houses and rooms. In these houses there are a total of 49 *opus tessellatum*, 3 *opus sectile*, 2 *opus signinum*, 6 *opus fliginum*, and 2 *opus segmentatum*. Mosaics are also to be found in the Archaeological Museum, Sevillian houses, and in the store of Italica.

The mosaic of the Labyrinth (second century AD) is situated in the House of Neptune's Mosaic, which has 8 *opus tessellatum* and 1 *opus fliginum*. This house was excavated in the 1930–31 campaign, and among the restorations documented are those of the foundations and perimeter walls redone in the 1960s. The mosaic has a size of 6·55 × 5·35 m and a total area of 35·04 m². The theme represented is geometrical, with a labyrinth in whose centre are the remains of a figure, which has disappeared. The labyrinth design surrounds the missing central figure. On one of its sides there is a drawing of circles and stars. The mosaic has gaps due to missing fragments, and shows signs of instability, movements, and cracks, with a disintegrated base, poor adhesion between the different strata, and much dampness in the rainy periods of the year (Fig. 1).

The tesserae are cubic, stony, of four basic colours (red, yellow, grey and white). According to the *Rock-Color Chart* (1984) the range of colours is dusky red 5 R 3/4 to moderate red 5 R 4/6, dark yellowish orange 10

Fig. 1. Mosaic of the Labyrinth.

YR 6/6, medium light grey N 6 to medium grey N 5, and white N 9. On the borders, there are tesserae which are greyish pink 5 R 8/2 to moderate pink 5 R 7/4. The tesserae are usually from 1·2 to 1 cm^2 and at a density of 81 tesserae/100 m^2. The surface with tesserae is 34·58 m^2 (98·8%), while the missing fragments represent 0·42 m^2 (1·2%). Adhesion of the tesserae to the base is very poor or non-existent, and the mosaic has numerous bulges over its whole area. In some cases, the tesserae edges are covered with mortar, and in others there are edges eaten away with the mortar lifted and chipped. The surface of the mosaic is not smooth, but has bumps and depressions which retain water in the wet season.

The tesserae are loosened, except those which have been restored. During the winter of 1987, a metallic structure was set up over the mosaic, which was covered at a height of 40 cm from the ground with wood and opaque plastics, leaving the sides open. This caused the appearance of rust stains on the mosaic. There are no reports on the state of conservation before the covering. At present, there is very abundant colonization of the mortars by mosses and of the tesserae by lichens. Gramineae and other vascular plants also appear among the mosses. The mosaic shows a lack of cleaning, increased by the deposit of organic matter and resins from the cypresses which border the paths, and are very close to this mosaic.

The mosaic of Tellus is found in the House of the Birds, which has 11 *opus tesellatum*. The house was excavated in the campaign of 1927–8. The foundations and perimeter walls were redone in the 1960s. The mosaic, from the second century AD, is 3·69 × 3·64 m, with a total of 13·43 m^2. The central motif represented the head of Tellus, Goddess of the Spring, and was stolen in November 1983, leaving a large central gap. The head was framed by a plaited ribbon in the form of a circle, around which was an octagon of alternate birds and vases, framed in rectangles. In the four vertices are circular motifs within squares (Fig. 2).

According to existing data, this mosaic has never been lifted, so that it is in place with the original Roman mortar, of lime and sand. The mortar is in a poor state. Many tesserae have loosened and bulges appear in the surface along with cracks, poor adhesion between strata, disintegrated base, instability, and movements. In wet periods, water accumulates in the centre of the mosaic, in the gap left by the robbery of the central motif. This is at a lower level and filled with cement, so that there is profuse saline efflorescence. The mosaic was covered from February to May 1987.

The tesserae of the mosaics of Tellus are cubic, regular and stony, vitreous or ceramic. The most frequent stony tesserae are white N 9, pale yellowish orange 10 YR 8/6 to greyish orange 10 YR 7/4, greyish orange

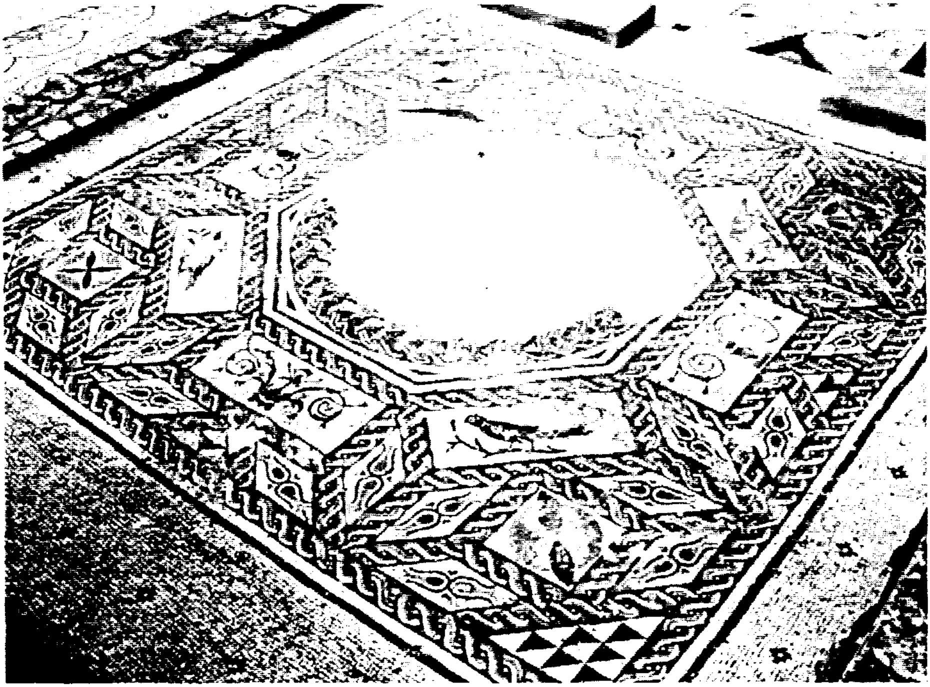

Fig. 2. Mosaic of Tellus.

pink 5 YR 7/2 to pale reddish brown 10 R 5/4, and medium bluish grey 5 B 5/1 to dark greenish grey 5 G 4/1. The ceramic tesserae are light brown 5 YR 5/6, while the vitreous tesserae have very diverse tone, the most plentiful being the following: very dark red 5 R 2/6, greyish green 10 G 4/2, dusky green 5 G 3/2, moderate blue green 5 BG 4/6, pale green 10 G 6/2, pale blue 5 PB 7/2, moderate yellow green 5 GY 7/4, dusky blue 5 PB 3/2 to greyish blue 5 PB 5/2, dark greenish yellow 10 Y 6/6, light brown 5 YR 5/6, and medium light grey N 6. The size of the tesserae varies from 1 to 0·6 cm, and their density from 64 to 140 tesserae/100 cm^2. Some 12 m^2 of the surface of tesserae has been conserved, representing 89·3%, with 1·43 m^2 having disappeared. The tesserae are very poorly adhered to the base, with numerous bulges over all the surface, and loosenings and colour alterations by calcination at some points.

COLONIZATION OF BRICK

The mosaics of Italica are surrounded by perimeter walls of brick, cemented with lime, sand, ceramic, and mortar. These define and separate the different rooms of each house, and were made in the 1960s.

The lichen, bryophyte and vascular flora of the bricks is not significantly different in the two mosaics. In both, a total of five species of lichens has been identified: *Acarospora* sp. (sterile), *Caloplaca irrubescens*, *Lecanora muralis*, *Verrucaria nigrescens*, and *Xanthoria parietina* (Table 1). *Caloplaca irrubescens* and *X. parietina* are the most abundant, and their thalli appear fertile.

The bryophyte flora, present in the mortar between bricks, is similar to that found on the mortars in which the tesserae are set. Prominent species are *Bryum argenteum* and *Funaria hygrometrica*.

The vascular flora colonizing the surroundings of the mosaics and bricks — in the latter case normally from the mortar, in the fissures in the bricks themselves, and on their edges — is typically nitrophilic (Table 2), comparable to that found in the surroundings of the Roman city (very altered due to the impact of human activity), and in the uncultivated surrounding land (notably nitrophilic due to grazing), with a large number of small mammals (mice, moles, and rabbits), both in the already excavated places and the unexcavated.

COLONIZATION OF MORTARS

The mortars are formed of lime and sand. They are porous and permeable in nature, facilitating the transport of water and salts in solution from the subsoil, so enriching their environment in nutrients. The surface is irregular, facilitating deposit of particles, dust, organic matter, and spores. In contrast to the smooth, hard surfaces of the tesserae, which restrict biological colonization, the mortars, with a higher water-retention capacity and lower cohesion of material, allow a more efficient colonization, firstly of algae and then mosses or lichens.

The mortars are subject to mechanical disintegration caused by endolithic and epilithic crustose lichens. The foliose lichens appear later. Among the lichens colonizing the mortars, two well-defined strategies stand out: one, of those which colonize the mortars, from which they invade the tesserae, and the other, of those which colonize only the mortars.

Caloplaca chalybaea and *Lecidea deustata* are two lichen species representing the former strategy (Fig. 3), together with *Collema* sp. and *Caloplaca subpallida*. This latter always appears fertile and with small-sized thalli, although it also (rarely) appears growing on *Dermatocarpon* sp.

The species which colonize only the mortars is *Dermatocarpon* sp.,

TABLE 1
Lichens and Mosses in Italica Mosaics

Substrate	*Colour*	*Lichen*
Mosaic of Tellus		
Stone	White	*Aspicilia hoffmannii*
		Caloplaca aurantiaca
		Caloplaca chalybaea
		Caloplaca subpallida
		Caloplaca sp.
		Collema sp.
		Lecidea deustata
		Candelariella vitellina
Stone	Orange	*Caloplaca chalybaea*
		Lecidea deustata
Stone	Red	*Caloplaca chalybaea*
		Lecidea deustata
Stone	Grey	*Aspicilia hoffmannii*
		Caloplaca chalybaea
		Caloplaca sp.
		Candelariella vitellina
Ceramic	Brown	*Caloplaca* sp.
		Lecanora dispersa
		Verrucaria nigrescens
Vitreous	Red	*Caloplaca chalybaea*
		Rinodina sp.
Vitreous	Green	*Caloplaca* sp.
		Candelariella vitellina
		Rinodina sp.
Vitreous	Blue	*Caloplaca* sp.
		Candelariella vitellina
Mosaic of the Labyrinth		
Stone	Red	*Caloplaca chalybaea*
		Lecidea deustata
Stone	Orange	*Caloplaca chalybaea*
		Caloplaca sp.
		Lecidea deustata
Stone	White	*Aspicilia hoffmannii*
		Aspicilia radiosa
		Caloplaca chalybaea
		Caloplaca sp.
		Lecidea deustata

(continued)

TABLE 1—*contd.*

Stone	Pink	*Aspicilia hoffmannii*
		Caloplaca chalybaea
		Caloplaca sp.
		Lecidea deustata
Stone	Grey	*Aspicilia radiosa*
		Caloplaca chalybaea
		Lecidea deustata
		Verrucaria nigrescens
	Mosaics of Tellus and the Labyrinth	
Brick	Brown	*Acarospora* sp.
		Caloplaca irrubescens
		Lecanora muralis
		Verrucaria nigrescens
		Xanthoria parietina
Mortar	White	*Aspicilia radiosa*
		Caloplaca chalybaea
		Caloplaca subpallida
		Caloplaca sp.
		Collema sp.
		Dermatocarpon sp.
		Lecanora dispersa
		Lecidea deustata
		Rinodina sp.
	Mosaic of the Labyrinth	
Substrate	*Colour*	*Moss*
Mortar	White	*Aloina aloides*
		Barbula sp.
		Bryum argenteum
		Bryum sp.
		Crassidium sp.
		Didymodon trifarius
		Funaria hygrometrica
		Funaria sp.
		Grimmia sp.
		Gymnostomum sp.
		Pottia sp.

appearing on the mortar between white tesserae, though infrequently and always in the sterile thallus form, indicating that they are not in their optimum ecological state. *Lecanora dispersa* and *Rinodina* sp. are also scarce but fertile species. Lastly, fertile *Caloplaca* sp. appears on mortars, and also on *Caloplaca chalybaea* and *Lecidea deustata*, as lichenicolous species.

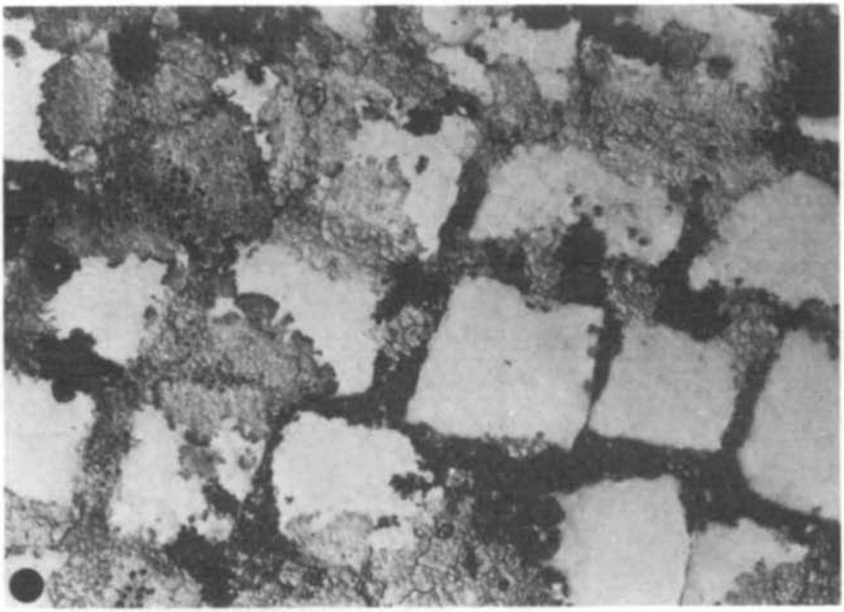

Fig. 3. *Caloplaca chalybaea* (white) and *Lecidea deustata* (black) on white stony tesserae and mortar. Mosaic of the Labyrinth.

When the pioneering community has reached maturity, and there is sufficient humus to retain and feed other higher species, the bryophytes can appear. These prepare the substrate for the invasion of vascular plants, normally nitrophiles. However, this enriching in humus does not need to be from lichens — the first colonizers may also be cyanobacteria and algae, which grow on sites where the water is retained longer (generally mortars), forming patinas which develop rapidly in wet periods. These algae are found on lime substrates both in free state and in close relationship with bryophytes (Saiz-Jimenez, 1984).

In Italica, the bryophytes colonize the mortars of the mosaics, preferentially those in shady areas or protected from the sun by the ornamental trees (mainly cypresses) which line the paths, as is the case of the Labyrinth mosaic. With respect to the mosses, the most common species are *Bryum argenteum*, *Funaria hygrometrica*, *Didymodon trifarius*, *Aloina aloides* and *Crassidium sp.*, which are found fertile. Species of the genus *Grimmia*, *Pottia*, *Barbula*, *Bryum*, *Funaria*, and *Gymnostomum* are less abundant. Of the other bryophyte group, the liverworts, the presence of *Lunularia* sp. stands out. This is relatively abundant on the Labyrinth mosaic, both on the mortar and on the borders of the mosaic.

The effect of the mosses on the mortars is important. Optical and electron microscopy reveal the profuse network of rhizoids in the areas

TABLE 2
Vascular Plants in the Archaeological Site of Italica

Species	*Location*[a]	*Abundance*[b]	*Cultured/wild*[c]
Acacia sp.	S	1	C
Acanthus molle	B	1	C
Anchusa azurea	B	1	W
Andryala integrifolia	B	2	W
Arbutus unedo	B	1	C
Avena sativa	B	2	W
Avena sterilis	B	2	W
Borago officinalis	S	1	W
Bromus sterilis	B	2	W
Carpobrotus acinaciformis	S	1	C
Citrus lemon	S	1	C
Centaurea pullata	B	2	W
Convolvolus altheoides	B	2	W
Crepis vesicaria	B	2	W
Chrysanthemun coronarium	B	1	W
Cupressus sempevirens	B	2	C
Cupressus macrocarpa	B	1	C
Dactylis glomerata	B	2	W
Daucus carota	B	1	W
Ditrichia viscosa	B	2	W
Echallium elaterium	B	1	W
Echium plantagineum	B	1	W
Echium vulgare	B	1	W
Euphorbia sp.	B	1	W
Ficus carica	S	1	C
Hordeum vulgare	B	2	W
Hordeum murinum	B	2	W
Jasione montana	B	1	W
Lactuca sp.	S	1	W
Lagurus ovatus	B	1	W
Lamarkia aurea	B	2	W
Lantana camara	S	1	C
Lavatera trimestris	B	2	W
Linum sp.	B	3	W
Lolium rigidum	B	2	W
Malva hispanica	B	2	W
Malva nicaensis	B	1	W
Mercurialis annua	B	3	W
Nerium oleander	S	1	C
Nonea sp.	B	1	W
Olea europaea	S	1	C
Palenis spinosa	B	3	W
Papaver rhoeas	B	2	W
Pelargonium sp.	S	1	C

TABLE 2—*contd.*

Species	*Location*[a]	*Abundance*[b]	*Cultured/wild*[c]
Phalaris canariensis	B	2	W
Phoenix canariensis	S	1	C
Pinus halepensis	S	1	C
Plantago lanceolata	B	2	W
Populus alba	S	1	C
Pulicaria paludosa	B	3	W
Punica granatum	S	1	C
Rosmarinum officinalis	S	1	C
Scorpiurus muricatus	B	3	W
Silybum marianum	S	1	W
Sonchus tenerrimus	B	2	W
Trisetum paniceum	B	2	W
Vitis vinifera	S	1	C

[a] S, surroundings of the mosaics and houses; B: border of the mosaics.
[b] 1, rare; 2, frequent; 3, very frequent.
[c] C, cultured; W, wild.

of mortar. Rhizoids may penetrate the mortar down to the base allowing easy access of water to deep levels (Garcia-Rowe & Saiz-Jimenez, 1989). Rhizoids, however, are not capable of penetrating the tesserae. The mosses contribute to organic enrichment of the substrate and the formation of humus, opening the way to invasion by vascular plants. Vascular plants are more destructive than mosses, and have even completely destroyed some mosaics, such as that which was originally in the passage of the House of Neptune's Mosaic, just beside the Labyrinth mosaic.

COLONIZATION OF TESSERAE

It is generally considered that a period of some years must pass before lichens establish themselves on new substrates. Most of the mosaics were excavated after 1919, predominantly between 1924 and 1932. Since then there has been no regular cleaning to ensure removal of dust or deposits of organic matter — therefore lichens have had the chance of developing over a long period of time.

The stony tesserae are usually carbonate rocks, in which the presence of organic matter or iron oxides determines the colour tone. Thus the red tesserae are usually limestones with goethite, the yellowish tesserae limestones with iron oxides, and the grey tesserae with varying percentages of organic matter, although one of the types of dark tesserae seems to be a volcanic rock (Lopez de Azcona & Mingarro, in press).

The white tesserae usually have the most abundant colonization, and also the most notable lichen invasion, particularly *Lecidea deustata*. In Italica, the colonization of white tesserae by species of *Caloplaca chalybaea* and *Lecidea deustata* is particularly profuse (Fig. 3). Although these may colonize from the mortar, they are also capable of direct colonization of the tesserae. The same situation has been observed with the pink stony tesserae. In addition, both lichens are very frequent in all the mosaics of the archaeological site. *Collema* sp. and *Caloplaca subpallida*, however, do not seem capable of direct colonization of the tesserae, and, in the mosaic of Tellus, invade the white tesserae from the mortar.

In the Mosaic of Tellus, *Candelariella vitellina* colonizes both the white and grey tesserae, while *Aspicilia radiosa* does the same in the Labyrinth mosaic. In the mosaic of Tellus, *Caloplaca aurantiaca* is found, in an isolated form, on one white stony tessera.

With respect to the vitreous tesserae, lichen colonization is much more restricted, both on other mosaics studied and that of Tellus. It is noteworthy that the red tesserae are colonized in the fissures by *Rinodina* sp. and also *Caloplaca chalybaea*, which attack them from the mortar. The green tesserae are colonized by *Candelariella vitellina*, *Rinodina* sp. and *Caloplaca* sp. (Fig. 4). An endolithic *Caloplaca* sp. with a granular-edged apothecium, different to that previously mentioned, appears on one grey tessera, together with a *Candelariella vitellina*.

The ceramic tesserae of the Tellus mosaic are colonized by endolithic *Caloplaca* sp., *Lecanora dispersa* and *Verrucaria nigrescens*, the latter colonizing from the mortar.

DETERIORATION OF THE MOSAICS

Lichen attack of tesserae and mortars is both mechanical and chemical. It has been observed that lichens colonize, penetrate, and etch the minerals of which the tesserae are made. Furthermore, they attack the lime mortar between the tesserae, and some of these species are unable to colonize the tesserae from the mortar. However, it seems that the heaviest damage is caused by the mechanical effects due to disintegration and dissolving of the mortar, to frosts, and movement of poorly adhered tesserae by the activity of small mammals. To this must be added the

Fig. 4. An endolithic *Caloplaca* sp. on green vitreous tessera. Some apothecia are indicated with arrows. Mosaic of Tellus.

action of the moss rhizoids, which extensively invade the mortar in wet seasons, breaking the cohesion between tesserae and mortar, causing cracks and fractures, and thus preparing the substrate for subsequent vascular plant invasion.

With time, extensive growth of vascular plants (up to 57 different plants were recorded in the area of Italica, see Table 2) will result in loosening and removal of tesserae, and ultimately in the complete destruction of the mosaics. The activity of small mammals (mice, moles, and rabbits), by the formation of burrows and holes under the houses and mosaics, also contributes.

Manual cleaning and removal of the lichens, mosses, and vascular plants has been undertaken in the last few years in order to preserve the mosaics. The medium- and long-term effect of this method is doubtful, as pieces of the removed lichens and mosses may be deposited and retained on the irregularities of the mortar, thus enriching the substrate with organic matter and humus, favouring vascular plant invasion.

In the last 3 years, during which the evolution of the mosaics has been studied, a progressive deterioration has been shown. This is seen mainly in the loss of tesserae from the different mosaics, their removal, and the abundant and growing invasion of mosses on the Labyrinth mosaic.

Serious doubts are established on the conservation of the mosaics of the Archaeological Site of Italica, at least unless there is rapid work to impede development of bryophytes and vascular plants.

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DISCUSSION WITH REVIEWERS

Q. You refer to lichen attack of the tesserae and mortars as being both mechanical and chemical. Could you describe the characteristics that you look at in attributing attack to either category?

A. It is well known that lichens are able to withstand prolonged periods of desiccation, reabsorbing water and swelling quickly once it becomes available again. This can result in deterioration of the stone, particularly by successive expansion and contraction of the lichen on wetting and drying, because the saturated water content of lichens may vary between 150 and 300% of the dry weight. In addition, the trapping of water in the stone around the lichen could lead to frost damage in cold climates. The former process is assumed to be of importance in mechanical deterioration of mosaics, although difficult to observe by microscopy, while the second one can rarely be active under the climatologic conditions of Italica.

Chemical attack has been demonstrated by study of tesserae colonized by different lichen species. Once the lichen thalli were removed by digestion with hydrogen peroxide, the surface of the tesserae appeared deteriorated by a random distribution of pitting, attributed to the direct effect of acids excreted by lichens.

Q. Have you established a biocidal regimen for eradication of the lower plants from the mosaics? If so, what is it? Does it have any adverse effect on the tesserae? How often would a treatment need to be repeated?

A. The conservation and restoration of Italica's mosaics is the goal of both a EUROCARE project (EU-396 PROMOS) and a Spanish project: Italica '92: the mosaics and their natural framework — the houses. It is intended to rebuild most of the Roman houses, to which the mosaics belong. This will permit the development of a passive conservation concept through environmental control of the rooms, once the most deleterious impact — the exposure of mosaics to open air and subsequent colonization by lower plants — is eliminated.

Q. Occasionally questions are raised about whether or not lichens — specifically epilithic forms — protect the surface from other environmental deterioration more than they destroy the substrate. Could you comment on this and any general thoughts about when and if lichens should be removed from a monument?

A. Lichen deterioration can be regarded on a geological, rather than historical, time-scale. Observations of epilithic lichen growth in monuments, in both urban and rural environments, lead us to the conclusion that in rural, non-polluted areas the significance of stone damage caused in the short-term is generally negligible when compared with that originated by air pollution in urban environments. In these latter environments crustose lichens protect, to some extent, the stone against chemical agencies. In some cases, the lichens are even esthetically integrated in the monuments.

In general, lichens should be removed from surfaces of statues and mosaic pavements because of disfiguring and superimposing of colours and textures, thus provoking the unaesthetic appearance of the work of art. On the contrary, there are no definite criteria for removal of lichens from historic monuments and buildings, it depending on the extension and activity of the lichen species, stone type, air pollution levels, landscaping, etc.