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Literature on lichens and biodeterioration of stonework. IV*

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Abstract: Each reference is numbered progressively and is characterized by publication details, a brief abstract and one or more abbreviations referring to specific themes. The list is followed by an Analytical Index of the different themes, showing the numbers corresponding to the appropriate references in the Bibliographic list. A new topic (RV) has been introduced to identify the review articles.

Bibliographic List

1. **Adamo, P. & Violante, P. (2000)** Weathering of rocks and neogenesis of minerals associated with lichen activity. *Applied Clay Science* **16:** 229–256. **LM, OX, PB, PC, PR, PS, RV** [The biogeophysical and biogeochemical deterioration of rocks and the bioformation of new minerals due to lichens are reviewed. Physical disaggregation and fragmentation of the substratum, rock surface corrosion, mineral dissolution patterns, neogenesis of minerals (oxalates, iron oxides and hydroxides, siliceous relicts, alumino-silicates and carbonates) induced by lichen growth are summarized. Biodeterioration of historical monuments is also considered.]

2. **Adamo, P. (2000)** Lo studio della bioalterazione di substrati minerali indotta da licheni: applicazione di nuove metodologie analitiche. In *La Lichenologia in Italia bilancio di fine secolo* (P. Adamo & G. Aprile, eds) *Notiziario della Società Lichenologica Italiana* **13:** 62. **PB, PC** [Review of principal techniques, weathering processes and lichen-substratum interrelationships.]

3. **Adamo, P., Vingiani, S. & Violante, P. (2000)** I licheni *Stereocaulon vesuvianum* Pers. e *Lecidea fuscoatra* (L.) Ach. ed il muschio *Grimmia pulvinata* agenti di bioalterazione di una tefrite fonolitica dell'Etna (Sicilia). In *La Lichenologia in Italia bilancio di fine secolo* (P. Adamo & G. Aprile, eds) *Notiziario della Società Lichenologica Italiana* **13:** 3–64. **PB, PC, OX** [Different analytical techniques (XRF, XRD, SEM) were employed to study weathering of a phonolitic tephrite in Etna volcano (Sicily, Italy).]

4. **Altieri, A., Pietrini, A. M., Ricci, S. & Roccardi, A. (2000)** The temples of the archaeological area of Paestum (Italy): a case study on biodeterioration. In *Proceedings of 9th International Congress on Deterioration and Conservation of Stone* (V. Fassina, ed.): 433–443. Amsterdam: Elsevier. **LM** [Autotrophic microflora, lichens, bryophytes and higher plants growing on the temples of Athena, Neptune, and Basilica (Paestum, Italy) were identified. Lichens and higher plants prevail, and *Dirina massiliensis* is the most frequent epilithic lichen. *Bagliettoa parmigera* seems to have a bioprotecting action against erosive phenomena due to the action of intense rainfall.]

5. **Anonymous (1996)** Lichen growth rates used to determine building age. *ASPP Newsletter* **23:** 12. **LM** [A brief account of the use of lichen growth rate during a laboratory exercise.]

6. **Aptroot, A. & James, P. W. (2002)** Monitoring lichens on monuments. In *Monitoring with Lichens—Monitoring Lichens* (P. L. Nimis, C. Scheidegger & P. A. Wolseley, eds): 239–253. The Netherlands: Kluwer Academic Publishers. **LM, GE, RV** [In this chapter on biodiversity of lichens on monuments, their value for historical dating and their potential harmful effects on the monuments are described with emphasis on monitoring techiniques. The analysis is focused on European work in particular.]

7. **Ariño, X. & Saiz-Jimenez, C. (1994)** Granite weathering by the lichen *Rhizocarpon geographicum*. In *Granite Weathering and Conservation* (E. Bell & T. P. Cooper, eds): 33–35. Dublin: Director of Buildings' Office, Trinity College. **PR** [*Rhizocarpon geographicum* penetrates granite not only through the intergranular spaces, but also by active penetration by hyphae evidenced by the presence of perforations 4–5 μm in diameter. Development of associated communities of algae and heterotrophic bacteria is also observed.]

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O. Salvadori: Soprintendenza Speciale per il Polo Museale Veneziano—Laboratorio Scientifico, Cannaregio 3553, I-30131 Venice, Italy
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8. **Ariño, X. & Saiz-Jimenez, C. (1997)** Deterioration of the Elephant tomb (Necropolis of Carmona, Seville, Spain). *International Biodeterioration and Biodegradation* **40:** 233–239. **LM, OX** [The calcarenite of the Elephant Tomb showed a strong powdering of the surface caused by a loss of calcitic cement. Biological colonization was studied: cyanobacteria and algae were scarcely developed inside while many lichens covered the external surfaces of the stone. Environmental parameters were measured and the role of biological agencies in the rock deterioration discussed. *Diploschistes gypsaceus* chemically attacked calcarenite with the production of calcium oxalate, but the lichen cover seemed to give more stability to rock when compared with bare rock.]

9. **Ariño Vila, X. & Gómez Bolea, A. (2002)** Colonizacion de monumentos y construcciones petreas por los liquenes. Estudios realizados en la Peninsula Iberica. In *Biodeterioro de Monumentos de Iberoamerica* (C. Saiz Jimenez & H. A. Videla, eds): 95–108. Spain: CYTED. **SE, EP, LM** [Biological and abiotic (i.e. substratum and microclimate) factors affecting the colonization of stone and alterations induced by lichens are analysed. The state of the art research in the Iberian Peninsula on this topic is presented.]

10. **Ariño, X., Gómez-Bolea, A. & Saiz-Jimenez, C. (1997)** Lichens on ancient mortars. *International Biodeterioration and Biodegradation* **40:** 217–224. **LM, PR** [Mortars of three archaeological sites of southern Spain are colonized by lichens of a variety of taxa. The mineralogical composition and the proportion of mineral aggregates affect the presence of some species and thallus types, and consequently the deterioration processes. Lichens produce extensive pitting and dissolution of minerals, especially calcite, and hyphae can penetrate to a depth of 5 mm.]

11. **Ariño, X., Gómez-Bolea, A., Hladun, N. & Saiz-Jimenez, C. (1995)** La colonizacion del Foro Romano de Baelo Claudia (Cadiz): aplicacion del tratamiento de imagenes al estudio de las comunidades liquenicas. In *XI Simposio Nacional de Botanica Criptogamica, Resumenes de Comunicaciones, Santiago de Compostela*: 221–223. **LM** [The lichen communities present on the sandstone floor of the Roman forum of Baelo Claudia (Spain) were studied. Two different communities were recognized: the first, dominated by *Caloplaca velana* on stone slabs covering the ancient drainage system, and the second, dominated by *Lecania turicensis*, *Verrucaria macrostoma* and *Collema crispum* var. *metzleri*, on stone slabs covering the clayey soil. The distribution maps of the lichens were digitized to trace the evolution of communities in time.]

12. **Ascaso, C. & Wierzchos, J. (1996)** Study of the weathering processes of granitic micaceous minerals by lichen activity. In *Degradation and Conservation of Granitic Rocks in Monuments, Proceedings of the EC Workshop* (M. A. Vicente, J. Delgado-Rodrigues & J. Acevedo, eds): 411–416. Protection and Conservation of the European Cultural Heritage, Research Report No 5. **PR, PS** [The effects on granitic rocks of *Lecidea auriculata*, *Parmelia conspersa* and *Aspicilia intermutans* were studied. Hyphal and algal penetration caused the separation and microdivision of the biotite layers. EDS analyses indicated a considerable potassium depletion on the sheets of exfoliated mica penetrated by lichens.]

13. **Ascaso, C., Wierzchos, J. & Castello, R. (1998)** Study of the biogenic weathering of calcareous litharenite stones caused by lichen and endolithic microorganisms. *International Biodeterioration and Biodegradation* **42:** 29–38. **PR, PS** [Bioweathering processes caused by lichens and accompanying endolithic microorganisms on calcareous stone of the Roman Cathedral of Jaca (Spain) were studied. *Diploicia canescens*, *Lecania rabenhorstii*, *Caloplaca* sp. and *Xanthoria* sp. were examined with SEM equipped with BSE detector and EDS. Various types of stone damage were observed in chlorite and calcite; oxalates were almost non-existent. The most important bioweathering is induced by fungi.]

14. **Ascaso, C., Wierzchos, J. & De Los Rios, A. (1998)** *In situ* cellular and enzymatic investigations of saxicolous lichens using correlative microscopical and microanalytical techniques. *Symbiosis* **24:** 221–234. **OX, PR, PS** [*Aspicilia intermutans* and *Lecidea auriculata* from outcrop granitic rocks, and *Diploicia canescens* and *Lecania rabenhorstii* from calcareous rock of the Cathedral of Jaca (Spain) were studied using SEM-BSE, CLSM and EDS. Micaceous minerals are exfoliated and among biotite layers fungal hyphae and calcium oxalate crystals are present. Ultrastructural features were observed, and several samples were immunogold labelled in order to detect the Rubisco enzyme.]

15. **Ascaso, C., Wierzchos, J., Delgado Rodrigues, J., Aires-Barros, L., Henriques, F. M. A. & Charola, A. E. (1998)** Endolithic microorganisms in the biodeterioration of the Tower of Belem. *Internationale Zeitschrift für Bauinstandsetzen* **4:** 627–640. **BM, PR** [The Tower of Belem was colonized by various organisms, from endolithic bacteria to higher plants. Bacteria, algae, fungi and protolichens living on and inside the stone were studied by SEM operating in BSE detection mode. Surface roughness, subsurface porosity and flaking of the stone are consequences of the biocolonization. Bacteria and clay minerals are closely associated.]

16. **Ascaso, C., Wierzchos, J., Souza-Egipsy, V. & Delgado Rodrigues, J. (1999)** Application of electron microscopy in the study of monumental stones. In *Of Microbes and Art: the Role of Microbial Communities in the Degradation and Protection of Cultural Heritage. Book of Abstracts of the International Conference on Microbiology and Conservation (ICMC '99), Florence, June 1999:*113–117. **BM, PR** [Electron microscopy was used to determine the stage of biodeterioration produced by lithobiontic communities on limestone monuments. Photobionts (*Trebouxia* and cyanobacteria) and mycobionts showed a destructive activity producing stone cavities following the cellular outline. An increase of surface roughness, porosity and disintegration of stone surfaces was observed.]

17. **Ascaso, C., Wierzchos, J., Souza-Egipsy, V., De Los Rios, A. & Delgado Rodrigues, J. (2002)** *In situ* evaluation of the biodeteriorating action of

microorganisms and the effects of biocides on carbonate rock of the Jeronimos Monastery (Lisbon). *International Biodeterioration and Biodegradation* **49:** 1–12. **EP, CM, PR, PS** [The biodeteriorating effects of microorganisms and lichens (*Thyrea*, *Aspicilia*, *Verrucaria* and *Caloplaca*) on carbonate rock of the Jeronimos Monastery (Lisbon) were studied. Cyanobacteria produced bowl- or pear-shaped cavities in the rock, and a mineral network structure probably related to calcium mobilization was observed near them. Neoformation of biogenic carbonate was detected in thalli of *Thyrea*. Three biocides (Algophase®, Metatin®, and Preventol R80®) were tested. Ultrastructural alterations were observed in the photobiont of *Thyrea*; Preventol R80® is the most efficient product leading to the complete disorganization of cyanobacteria cells.]

18. **Bajpai, P. K., Bajpai, R. P. & Sinha, G. P. (1993)** Study of the effect of biocides on lichens using biophoton emission. In *Biodeterioration of Cultural property* 2, *Proceedings of the 2nd International Conference*, October 5–8, 1992, Pacifico Yokohama, Japan (K. Toishi, H. Arai, T. Kenjo & K. Yamano, eds): 619–623. Tokyo: International Communications Specialists. **CM** [Biophotonic activity is tested and proposed as a method for evaluating the efficiency of biocides against lichens. The minimum concentration of five biocides (BAC, Polycide, Sodium pentachlorophenol, Diuron, P-quat dichloride) necessary for the eradication of *Cladia aggregata*, *Diploschistes actinostomus*, *Parmelia tinctorum*, *Physcia* sp., *Usnea baileyi* and *Verrucaria* sp. was measured.]

19. **Barker, W. W. & Banfield, J. F. (1996)** Biologically versus inorganically mediated weathering reactions: relationships between minerals and extracellular microbial polymers in lithobiontic communities. *Chemical Geology* **132:** 55–69. **PS, PC, PB, OX** [Biogeophysical and biogeochemical weathering activities of two crustose lichens (*Rhizocarpon grande* and *Porpidia albocaerulescens*) on the silicate rocks, amphibole syenite, of Wisconsin were examined by HRTEM, SAED and EDS. Lichen hyphae penetrate the rock surface to a depth of 10 mm. Several communities of bacteria, algae and fungi inhabit the lichen-mineral interfaces. Extracellular biopolymers, predominantly acidic mucopolysaccharide gel, produced by bacteria and fungi coat all the mineral surface. Physicochemical transformation of ferrohastingsite to topotactically oriented smectite and nanocrystalline goethite may involve a combination of structural inheritance and dissolution/transport of dissolved constituents.]

20. **Barker, W. W. & Banfield, J. F. (1998)** Zones of chemical and physical interaction at interfaces between microbial communities and minerals: a model. *Geomicrobiology* **15:** 223–244. **PB, PR** [Four zones of biogeochemical weathering of silicate mineral assemblages colonized by lichen lithobiontic communities are proposed based on electron microscopic studies.]

21. **Barker, W. W., Welch, S. A. & Banfield, J. F. (1997)** Biogeochemical weathering of silicate minerals. In *Geomicrobiology*. *Interactions between Microbes and Minerals*. *Reviews in Mineralogy*, *Mineralogical Society of America* (J. F. Banfield & K. H. Nealson, eds): 391–428. **PB, RV** [Detailed review with numerous references.]

22. **Barquin Sainz de la Maza, P. & Terron Alfonso, A. (1998)** Lichen communities in the cathedral of Leon. *Aerobiologia* **13:** 191–197. **LM, SE** [Two lichen communities were recognized on dolomite and limestone of the cathedral of Leon (North Western Spain). The first, dominated by the genera *Caloplaca*, *Aspicilia* and *Rinodina*, developed on substrata with high eutrophication; the second one, dominated by the genera *Physcia*, *Physconia* and *Phaeophyscia*, was spread on substrata with accumulated organic matter and produced a higher degree of physical biodeterioration. The distribution of lichen species is highly correlated with the ecological indices.]

23. **Bartoli, A., Massari, G. & Ravera, S. (1998)** The lichens of the Mausoleum of Manatius Plancus (Gaeta). *Sauteria* **9:** 53–60. **LM** [A floristic and phytosociological study that, on the basis of 63 relevès, lists 37 species on limestone blocks of the Mausoleum, a building on top of Mount Orlando in southern Italy.]

24. **Bell, E., Dowding, P. & Cooper, T. P. (1992)** The effect of a biocide treatment and a silicone treatment on the weathering of limestone. *Environmental Technology* **13:** 687–693. **CM** [A relatively short-term (68 days) study is presented on the effects of a biocide treatment, pentachlorophenol, and a silicone water repellant on the dissolution processes of limestone. Biodeterioration of stone by lichens is briefly discussed.]

25. **Brady, P. V., Dorn, R. I., Brazel, A. J., Clark, J., Moore, R. B. & Glidewell, T. (1999)** Direct measurement of the combined effects of lichen, rainfall, and temperature on silicate weathering. *Geochimica and Cosmochimica Acta*, **63:** 3293–3300. **PS, PR, PC** [Weathering of silicates in basalt flows in Hawaii under different environmental conditions and in the presence or absence of lichens is studied by digital imaging.]

26. **Bratt, C. (1997)** Lichens of Cabrillo National Monument, Point Loma, San Diego. *Bulletin of the California Lichen Society* **4:** 1–2. **LM** [Fifty taxa are reported.]

27. **Building Research Establishment Digest (1992)** Control of lichens, moulds and similar growths. *BRE Digest* **370. CM** [The use of surface biocides and fungicidal paints, and brushing is illustrated together with advice for treating outside surfaces, attacked by biological growths. Furthermore the article provides a list of active ingredients contained in products cleared as biocides safe for use.]

28. **Caneva, G., Piervittori, R. & Roccardi, A. (1998)** Ambienti esterni: problematiche specifiche. In *Aerobiologia e Beni culturali. Metodologie e tecniche di misura* (P. Mandrioli & G. Caneva, eds): 247–251. Fiesole, Firenze: Nardini Editore. **BM, LM** [Specific problems related to aerobiological monitoring for the conservation of cultural artifacts outdoors are detailed and discussed with emphasis on methods for data collection and analysis.]

29. **Cao, J. & Wang, F. (1998)** Reform of carbonate rock subsurface by crustose lichens and its environmental significance. *Acta Geologica Sinica* **72:** 94–99. **SE** [Results of comparative field experiments between biokarst samples underneath crustose lichens and fresh rock samples with the same composition and texture are shown. Crustose lichens are shown to promote surface corrosion of carbonate rocks.]

30. **Cao, J. & Wang, F. (1998)** Relationships of biokarst microforms of algae and lichens and the terrestrial environment. *Geological Review* **44:** 656–661. **SE** [A study carried out in China on limestone weathering. In Chinese, with English abstract.]

31. **Carballal, R., Paz-Bermudez, G., Sanchez-Biezma, M. J. & Prieto, B. (2001)** Lichen colonization of coastal churches in Galicia: biodeterioration implications. *International Biodeterioration and Biodegradation* **47:** 157–163. **LM, GE, SE** [Lichen colonization of four granite churches in coastal areas in Galicia (NW Spain) was studied and compared with that on non-coastal churches. A group of characteristic species on granite monuments was recognized under very different environmental conditions. A protective role of lichens against salt disaggregation was hypothesized.]

32. **Carter, N. (2000)** Small ecological project progress report: controls on lichen species distribution, community structure and species richness on limestone heritage buildings in Oxford and the Cotswolds. *British Lichen Society Bulletin* **86:** 33–35. **LM, CM** [The effects of environmental factors (altitude, air quality, surface, aspect, height from ground, and substratum composition) on lichen distribution were studied on 15 churches. Exposure, architectural features and substratum composition were shown to affect lichen colonization].

33. **Chen, J., Blume, H. P. & Beyer, L. (2000)** Weathering of rocks induced by lichen colonization—a review. *Catena* **39:** 121–146. **LM, OX, PB, PC, PR, PS, RV** [The review deals with physical and chemical effects induced by lichens on different substrata (sandstone, basalt, granitic and calcareous rocks). Weathering rate of rocks promoted by lichens and protective effects of lichen against weathering processes are considered.]

34. **Childers, B. B. (1994)** Long-term lichen removal experiments and petroglyph conservation: Fremont County, Wyoming, Ranch Petroglyph Site. *Rock Art Research* **11:** 101–112. **CM** [Fifty petroglyphs on sandstone outcrops in Wyoming have been studied for the past 10 years. Prior to the experiments only 70% of the figures were visible and many petroglyph elements within the figures were covered by lichens. Most of the lichen cover has been removed without brushing, and the petroglyph site will be monitored for another 10 years to determine how successful the experiments will be in providing protection from further lichen growth.]

35. **Chu, F. J., Seaward, M. R. D. & Edwards, H. G. M. (1998)** Application of FT-Raman spectroscopy to an ecological study of the lichen *Xanthoparmelia scabrosa* in the supralittoral zone, Hong Kong. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy* **54:** 967–982. **OX** [Samples of *Xanthoparmelia scabrosa*, a foliose lichen collected from supralittoral sites in Hong Kong, were examined with FT-Raman scpectroscopy. A multivariate analysis of the Raman spectra and some environmental indicators, such as heavy metals, was carried out.]

36. **De Los Rios, A., Wierzchos, J. & Ascaso, C. (2002)** Microhabitats and chemical microenvironments under saxicolous lichens growing on granite. *Microbial Ecology* **43:** 181–188. **PS, PR** [Relationship between some foliose (*Lasallia hispanica*, *Parmelia omphalodes*) and fruticose (*Cornicularia normoerica*) saxicolous lichens and microorganisms growing on granite are examined, with particular attention to geophysical and geochemical processes.]

37. **Dillon, P., Skeggs, S. & Goodey, C. (1992)** Some investigations on habitats of lichens on sarsen stones at Fyfield Down, Wiltshire. *The Wiltshire Archaeological and Natural History Magazine* **85:** 128–139. **GE** [The results of two investigations on aspects of the physicochemical environments of two habitat types for lichens on sarsen stones at Fyfield Down are reported. The authors propose limits to the tolerance approach for equating lichen status with the physicochemical environment. They review changes in the physicochemical environment in the context of long-term history of the landscape.]

38. **Dobson, F. S. (1997)** Lichens on man-made surfaces. Encouragement and Removal. *British Lichen Society*, London. 4 unnumbered pages. **LM** [Leaflet for popular distribution.]

39. **Earland-Bennett, P. M. (1999)** Colchester walls. *British Lichen Society Bulletin* **85:** 1–4. **LM, BM** [A comparison is made between the lichen flora on a Roman wall before and after cleaning and rebuilding.]

40. **Edwards, H. G. M. (1998)** Another view of the world. *Chemistry and Industry*: 261–264. **PS** [General view of uses for Raman spectroscopy, including study of biodeterioration by lichens.]

41. **Edwards, H. G. M. (1998)** Raman spectroscopy of fresco fragment substrates. *Asian Journal of Physics* **7:** 383–389. **PS, PR** [The paper includes information on biodeterioration by *Dirina massiliensis*.]

42. **Edwards, H. G. M. & Perez, F. R. (1999)** Lichen biodeterioration of the Convento de la Peregrina, Sahagún, Spain. *Biospectroscopy* **5:** 47–52. **OX** [Destructive colonization of monumental stonework is demonstrated for lichens on the wall paintings inside the Convent. Lichen encrustations (*Diploschistes scruposus*) were analysed using Raman spectroscopy.]

43. **Edwards, H. G. M. & Russell, N. C. (1998)** Vibrational spectroscopic study of iron (II) and iron (III) oxalates. *Journal of Molecular Structure* **443:** 223–231. **OX** [Vibrational spectroscopic study of iron (II) and iron (III) oxalates. The characterization of molecular species may better determine their role in the biodeteriorative strategies operating in lichen colonies on sandstone.]

44. **Edwards, H. G. M., Gwyer, E. R. & Tait, J. K. F. (1997)** Fourier transform Raman analysis of paint fragments from biodeteriorated Renaissance frescoes.

Journal of Raman Spectroscopy **28:** 677–684. **OX, PS** [Study of frescoes with the paint affected by *Dirina massiliensis* f. *sorediata*.]

45. **Edwards, H. G. M., Drummond, L. & Russ, J. (1998)** Fourier-transform Raman spectroscopic study of pigments in native American Indian rock art: Seminole Canyon. *Spectroschimica Acta Part A: Molecular and Biomolecular Spectroscopy* **54:** 1849–1856. **PS, OX** [Samples of rock-art painting and pieces of shelter wall (*c*. 3500 years BP) were obtained from south-western Texas. The Raman microscope spectra of the prehistoric rock-art samples show several features of interest regarding the pigments and their substrata. The red pigment is confirmed to be red ochre [iron (III) oxide and clay] whereas the black pigment is manganese (IV) oxide. White areas of the paintings are identified as whewellite. The black pigmented areas contained Raman microscopic evidence for organic matter which was propably used as a binding agent.]

46. **Edwards, H. G. M., Holder, J. M. & Wynn-Williams, D. D. (1998)** Comparative FT-Raman spectroscopy of *Xanthoria* lichen-substratum systems from temperate and antarctic habitats. *Soil Biology and Biochemistry* **30:** 1947–1953. **PS, OX** [Raman spectroscopic analyses of pigments and oxalate content in a lithic moss, *Bryum argenteum*, and three *Xanthoria* species are reported. The epilithic *X. elegans* and *X. parietina* and their substrata (sandstone, granodiorite outcrops) and the epiphytic *X. mawsonii* from Antarctic and temperate habitats with widely different climatic features, especially in UVB-radiation receipt under the Antarctic ozone hole, were analysed.]

47. **Edwards, H. G. M., Farwell, D. W., Perez, F. R. & Villar, S. J. (1999)** Spanish mediaeval frescoes at Basconcillos del Tozo: a Fourier transform Raman spectroscopic study. *Journal of Raman Spectroscopy* **30:** 307–311. **PS, OX** [FT-Raman spectroscopy is used to study the pigments (reds, black, yellow and blue) and substrata of the late mediaeval frescoes.]

48. **Edwards, H. G. M., Holder, J. M., Seaward, M. R. D. & Robinson, D. A. (2002)** Raman spectroscopic study of lichen-assisted weathering of sandstone outcrops in the High Atlas Mountains, Morocco. *Journal of Raman Spectroscopy* **33:** 449–454. **OX** [The biodeterioration of sandstone by *Aspicilia caesiocinerea* agg. was examined under stressed environmental arid mountain conditions. FT Raman spectroscopy was applied to studies of lichen-substratum transects to identify key wavenumber spectral markers of the biological changes.]

49. **Friedmann, E. I. & Weed, R. (1987)** Microbial trace-fossil formation, biogenous, and abiotic weathering in the Antarctic Cold Desert. *Science* **236:** 703–705. **BM** [Includes information on cryptoendolithic lichens.]

50. **Galsomies, L., Robert, M. & Orial, G. (1996)** Biological factors in the weathering of historical monuments in granite (Brittany—France). In *Degradation and Conservation of Granitic Rocks in Monuments, Proceedings of the EC Workshop* (M. A. Vicente, J. Delgado-Rodrigues & J. Acevedo, eds): 95–101. Protection and Conservation of the European Cultural Heritage, Research Report no. 5. **BM, LM** [The role of some autotrophic bacteria and lichens in the deterioration of granite monuments in Brittany was studied. Among the bacteria of the nitrogen cycle only nitrifying bacteria were present in high numbers. Thin sections of *Tephromela atra*, *Diploicia canescens* and an endolithic lichen, stained with a fluorochrome and observed by optical microscope, showed extensive disintegration, inclusion of feldspars in the medulla and hyphae penetration to a few mm into the granite.]

51. **Garcia-Rowe, J. & Saiz-Jimenez, C. (1989)** Colonizacion y alteracion de mosaicos por liquenes y briofitos. In 1° *Coloquio Nacional de Conservacion de Mosaicos*, *Duputacion de Palencia*: 60–84. **LM** [The colonization of some mosaics of Italica (Spain) by lichens and bryphytes was analysed. The different strategies of colonization and their attachment to rock and minerals were discussed.]

52. **Garcia-Rowe, J. & Saiz-Jimenez, C. (1991)** Colonizacion y alteracion de la piedra por liquenes, briofitos y plantas superiores en las catedrales de Salamanca, Sevilla y Toledo. In *Jornadas Restauracion y Conservacion de Monumentos*: 71–79. Madrid: Instituto de Conservacion y Restauracion de Bienes Culturales. **LM** [A floristic list is given of lichens, bryophytes and plants present on the cathedrals of Salamanca, Seville and Toledo (Spain) with some ecological data.]

53. **Garcia-Rowe, J. & Saiz-Jimenez, C. (1992)** A case study on the corrosion of stone by lichens: the mosaics of the Roman remains of Italica. In *Microbial Corrosion, Proceedings of the 2nd EFC Workshop* (C. A. C. Sequeira & A. K. Tiller, eds): 275–281. London: The Institute of Materials. **LM, PR** [Some tesserae of the mosaics of Italica (Spain) colonized by *Caloplaca chalybaea*, *C. vitellinula*, *Lecidea deustata*, and *Verrucaria nigrescens* were studied. SEM observations showed extensive corrosion in the form of pits and channels and well developed etching attributed to the action of hyphae.]

54. **Gómez-Bolea, A., Arino, X., Balzarotti, R. & Saiz-Jimenez, C. (1999)** Surface treatment of stones: consequences on lichenic colonization. In *Of Microbes and Art*: *the Role of Microbial Communities in the Degradation and Protection of Cultural Heritage*. *Book of Abstracts of the International Conference on Microbiology and Conservation* (*ICMC '99*), *Florence*, *June 1999*: 233–237. **CM** [The portico of the church of Scurano (Parma, Italy) was examinated six years after restoration. A 2% solution of benzalkonium chloride in water (50%) and 3% Algophase in trichloroethane were used as biocides, followed by the application of a water-repellent. No evidence of recent growth of, or recolonization by cyanobacteria, algae and lichens was observed. A well-developed community of lichens is present on the untreated walls near the portico.]

55. **Hale, M. E. (1975)** Informe sobre el crecimiento de liquenes en los monumentos de Copan, Honduras. *Yaxkin* **1:** 6–9. **LM, CM** [A study on the ecology and cleaning techniques of lichens on Honduras monuments.]

56. **Holder, J. M., Wynn-Williams, D. D., Perez, F. R. & Edwards, G. M. (2000)** Raman spectroscopy of pigments and oxalates *in situ* within epilithic lichens:

Acarospora from the Antarctic and Mediterranean. *New Phytologist* **145:** 271–280. **OX** [Micro-spatial distribution of pigments *in situ* within intact viable thalli of epilithic *Acarospora chlorophana* and *A. oxytona*, exposed to contrasting environmental stress, are examined by FT Raman spectroscopy. Their differential production of calcium oxalate and modification of the substratum during colonization and establishment are shown.]

57. **Kumar, R. & Kumar, A. V. (1999)** Biodeterioration of stone in tropical environments. In *Research in Conservation:* 1–85. Los Angeles: The Getty Conservation Institute. **BM, CM, LM** [A review of research on biodeterioration of stone in tropical regions. Bacteria, algae, fungi, lichens, mosses and higher plants found on historical buildings and monuments are reported, and the resultant biodeterioration they cause is discussed. Preventive and remedial methods are considered.]

58. **Lee, M. R. (1999)** Organic-mineral interactions studied by controlled pressure SEM. *European Microscopy and Analysis*: 23–25. **PR, PS** [*Rhizocarpon geographicum* encrusting granite at two localities was studied. Its main weathering effect seems to be a mechanical rather than a chemical process. Mineral quartz and alkali feldspar (Na, K) embedded in the lichen thallus are interpreted as particles of wind-borne dust. Spherical particles occurring within intercellular spaces are fly-ash derived from the burning of coal in a power station.]

59. **Lee, M. R. & Parson, I. (1999)** Biomechanical and biochemical weathering of lichen-encrusted granite: textural controls on organic-mineral interactions and deposition of silica-rich layers. *Chemical Geology* **161:** 385–397. **PS, PB** [The results of an investigation of mechanisms and rates of biomechanical and biochemical weathering of Devonian Shap Granite (north-west England) by *Rhizocarpon geographicum* are described. The fungal hyphae exploit pores along cleavages and fractures at a rate of ≥ 0.002–0.003 mm yr^{-1}. Biotite, susceptible to biomechanical action, has been fragmented in <122 years. Grains of biomechanically weathered biotite show the clearest evidence of biochemical weathering. No oxalate minerals were found within the thallus. The role of *R. geographicum* in biochemical weathering is limited to the leaching of biotite and possibly etching of feldspar and deposition of a silica-rich substance. This substance may well play a protective role by covering mineral surfaces and cementing intragranular pores, thus inhibiting access of hyphae and acids into the interior of mineral particles].

60. **Marcos Laso, B. (2001)** Biodiversidad y colonización liquénica de algunos monumentos en la ciudad de Salamanca (España). *Botanica Complutensis* **25:** 93–102. **BM** [A list of 52 species from some monuments in the city of Salamanca, Spain, is presented.]

61. **May, E., Lewis, F. J., Pereira, S., Tayler, S., Seaward, M. R. D. & Allsopp, D. (1993)** Microbial deterioration of building stone. *Biodeterioration Abstracts* 7(2)**:** 109–123. **BM, LM** [Review of damage induced by lichens, fungi, algae, and bacteria on building materials with many references.]

62. **McCarroll, D. & Viles, H. (1995)** Rock-weathering by the lichen *Lecidea auriculata* in an artic-alpine environment. *Earth Surface Processes and Landforms* **20:** 199–206. **PS** [A series of moraine ridges of different age has been used to examine changes in the influence of *Lecidea auriculata* on rock weathering through time. SEM observations demonstrated that this crustose lichen penetrates rock surfaces, and detaches, incorporates and expels flakes of rock.]

63. **Monte, M. & Nichi, D. (1997)** Effects of two biocides in the elimination of lichens from stone monuments: preliminary findings. *Science and Technology for Cultural Heritage* **6:** 209–216. **CM** [The effects of Metatin N5810/101, Velpar and Diuron were tested on some lichen species growing on the cathedral of Orvieto (Italy). The vitality of lichens was evaluated by direct observations of colour and shape of thalli, and examination of sections in epifluorescence microscopy. Biocides are very effective on *Haematomma ochroleucum*. They have less impact on *Diploicia canescens* and *Caloplaca aurantia* while *Dirina massiliensis* and *Lecanora sulphurea* are resistant to these substances.]

64. **Mottershead, D. & Lucas, G. (2000)** The role of lichens in inhibiting erosion of a soluble rock. *Lichenologist* **32:** 601–609. **PR, PC** [The protective role of lichens on exposed gypsum surfaces is discussed. Clear evidence of substratum protection from chemically aggressive rainwater is provided.]

65. **Nimis, P. L. & Salvadori, O. (1997)** La crescita dei licheni sui monumenti di un parco. Uno studio pilota a Villa Manin. In *Il restauro delle sculture lapidee nel parco di villa Manin a Passariano. Il viale delle Erme. Restauro nel Friuli-Venezia Giulia. Quaderni di studi e ricerche del Centro regionale di restauro dei beni culturali* **4:** 109–142. **LM, CM** [The lichen vegetation of a limestone statue at Villa Manin (north-east Italy) has been studied. Five different community-types were detected and the species described; evapo-transpiration and eutrophication are the two most important factors determining the variation of lichen vegetation on the statue. Four biocides (Algophase, Lichenicida 264, Metatin N58-10/101, Neo Desogen) were tested *in situ* on *Caloplaca flavescens*, *Aspicilia radiosa* and a mixed population of cyanobacteria and green algae. The effectiveness of these products was evaluated by examining lichen sections and microorganisms using fluorescence microscopy. Change of stone colours induced by treatments were measured by a colorimeter.]

66. **Nimis, P. L. (1999)** Opere d'arte e di storia: ecosistemi minacciati. In *Frontiere della Vita*, *Enciclopedia Italiana Treccani* **IV:** 531–541. **BM, CM, LM** [Biodeterioration of cultural heritage and restoration ecology are discussed. Deterioration of indoor, outdoor and submerged artworks, and organisms involved, are described. The paper evaluates preventive and remedial treatments but also emphasises the importance of some archaeological sites for biodiversity conservation.]

67. **Nimis, P.L. (2001)** Artistic and historical monuments: threatened ecosystems. In *Frontiers of Life, Part 2: Discovery and Spoilation of the Biosphere, Sect. II: Man*

and the Environment: 557–569. San Diego: Academic Press. **BM, CM, LM** [Biodeterioration of cultural heritage and restoration ecology are discussed. Deterioration of indoor, outdoor and submerged artworks, and the organisms involved, are described. The paper evaluates of preventive and remedial treatments but also emphasises the importance of some archaeological areas for biodiversity conservation.]

68. **Nimis, P. L., Seaward, M. R. D., Ariño, X. & Barreno, E. (1998)** Lichen-induced chromatic changes on monuments: a case-study on the Roman amphitheatre of Italica (S. Spain). *Plant Biosystems* **132:** 53–61. **LM** [In the Roman amphitheatre of Italica (S. Spain) the relationship between compositional variation of the vegetation, some ecological gradients and the chromatic modifications of the stone have been analyzed by multivariate analysis. The data processed by an automatic mapping program produce the first example of a model of lichen-induced chromatic changes.]

69. **Nishiura, T. & Ebisawa, T. (1993)** Conservation of carved natural stone under extremely severe conditions on the top of a high mountain. Elimination of lichens and protective treatment. In *Biodeterioration of Cultural Property 2, Proceedings of the 2nd International Conference, October 5–8, 1992, Pacifico Yokohama, Japan* (K. Toishi, H. Arai, T. Kenjo & K. Yamano, eds): 506–511. Tokyo: International Communications Specialists. **CM** [Three biocides (benzalkonium chloride, sodium hypochlorite and formaldehyde) were used to eliminate lichens covering inscriptions on stone (porphyrite). Cracks were filled with synthetic resins and an organo-silane solution was used to protect the stone. Four years after the treatment no lichen was found.]

70. **Nishiura, T., Okabe, M. & Kuchitsu, N. (1994)** Study on the conservation treatment of Irimizu Sanjusan Kannon—cleaning and protective treatment of a marble Buddha image. *Hozon kagaku* **33:** 67–72. **CM** [In Japanese. Three cleaning and protective treatments were carried out on a group of 32 marble Buddha statues.]

71. **Not R. & Lo Campo P. (1995)** Controllo dei biodeteriogeni in alcuni manufatti storico-artistici di Villa Giulia (Palermo) mediante impiego di biocidi. *Quaderni di Botanica ambientale ed Applicata* **6:** 189–199. **CM** [The results of tests with biocides carried out against a variety of organisms on different lithotypes are discussed and the most suitable control methods suggested.]

72. **Piervittori, R. & Caramiello, R. (2002)** Importance of biological elements in conservation of stonework: a case study on a Romanesque church (Cortazzone, N. Italy). In *Proceedings 3rd International Congress on Science and Technology for the Safeguard of Cultural Heritage in the Mediterranean Basin* (A. Guarino, ed.): 891–894. Spain: Universidad de Alcalá. **BM, CM** [A case study under way for investigating biodeterioration on a church of Piedmont (Italy) is reported.]

73. **Piervittori, R. & Roccardi, A. (1998)** Licheni. In *Aerobiologia e Beni culturali. Metodologie e tecniche di misura* (P. Mandrioli & G. Caneva, eds): 179–183. Fiesole, Firenze: Nardini Editore. **BM** [Lichen vegetative propagules and spores have never been considered in the analysis of airborne material. The authors suggest adapting techniques that have been used for sampling other aerodiffused biological particles to include lichen components in studies of airborne material.]

74. **Piervittori, R., Salvadori, O. & Isocrono, D. (1998)** Literature on lichens and biodeterioration of stonework III. *Lichenologist* **30:** 263–277. **RV** [A bibliographic review of 96 papers devoted to lichens and biodeterioration of stonework. The list is accompanied by an analytical index in which articles are classified (by article number) according to topic.]

75. **Pinna, D. & Salvadori, O. (1999)** Biological growth on Italian monuments restored with organic or carbonatic compounds. In *Of Microbes and Art*: *the Role of Microbial Communities in the Degradation and Protection of Cultural Heritage*. *Book of Abstracts of the International Conference on Microbiology and Conservation* (*ICMC '99*), *Florence, June 1999*: 149–154. **LM** [Some cases of biological growth occurring on several Italian monuments after treatment with resins are presented. An Etruscan altar of Pieve a Socana (Arezzo, Italy) treated with an acrylic resin shows lichen growth. *Caloplaca flavovirescens* and *Verrucaria nigrescens* are the most common species. The lichens penetrate among clasts and their hyphae adhere to the resin and, sometimes, fill stone microcavities covered with resins.]

76. **Pinna, D. & Salvadori, O. (2000)** Endolithic lichens and conservation: an underestimated question. In *Proceedings of 9th International Congress on Deterioration and Conservation of Stone, Venice* (V. Fassina, ed.): 513–519. Amsterdam: Elsevier. **EP, LM, OX** [Endolithic lichens from the Sanctuary of Macereto (Central Italy) and Trieste Karst (NE, Italy) were studied by different techniques. Their thalli show several features in common but some species also showed peculiar characteristics. The thallus organization of *Caloplaca* sp. from Macereto differed considerably from the other species. None of the species examined produced calcium oxalate.]

77. **Pinna, D., Biscontin, G. & Driussi, G. (1995)** La pulitura e il controllo della crescita biologica sui materiali lapidei. In *La pulitura delle superfici dell'architettura. Atti del convegno di studi, Bressanone*, *Scienza e beni culturali* **11**: 619–624. Padova: Libreria Progetto Editore. **CM** [Control of biological growth is often grouped together with cleaning measures and can be carried out by selective or non-selective methods. If the cleaning measures are non-specific for biodeteriogen treatment, they can promote an increase in microbiological growth. Control of biodeterioration should consist of specific treatments carried out after analyses which assess the nature of biodeteriogens and the damage to the surfaces.]

78. **Pinna, D., Salvadori, O. & Tretiach, M. (1998)** An anatomical investigation of calcicolous endolithic lichens from the Trieste karst (NE Italy). *Plant Biosystems* **132:** 183–195. **EP, SE, OX** [The anatomy of five endolithic lichens (*Acrocordia conoidea*, *Petractis clausa*, *Rinodina immersa*, *Verrucaria baldensis*, and *V. marmorea*) from the Trieste Karst was

thoroughly investigated. Samples were examined by histological and mineralogical techniques, and by SEM. Biomineralization products were sought by XRD, microXRD, and FTIR. Thallus development is relatively constant within populations of a single species, but differs considerably among species; several features peculiar to each species were revealed. Calcium oxalate was not detected. Some terms currently used to describe the anatomy of endolithic lichens are critically discussed, and the new terms ‘lithocortex’ and ‘pseudomedulla’ are introduced.]

79. **Prieto, B., Edwards, H. G. M. & Seaward, M. R. D. (2000)** A Fourier transform-Raman spectroscopic study of lichen strategies on granite monuments. *Geomicrobiology Journal* **17:** 55–60. **PB, OX** [A spectroscopic investigation carried out on samples of *Lecidea fuscoatra*, *Porpidia cinereoatra* and *P. macrocarpa*, growing in the same environmental conditions on granitic monuments. *Porpidia cinereoatra* was the most aggressive, being able to deteriorate granite by both chemical and physical weathering processes. Physical deterioration mainly affects quartz and feldspar, whereas plagioclase is seriously affected by chemical deterioration that gives rise to the neoformation of calcium oxalate and gypsum.]

80. **Prieto, B., Rivas, M. T., Silva, B. M. & Lopez de Silanes, M. E. (1996)** Ecological characteristics of lichens colonizing granite monuments in Galicia (north-west Spain). In *Degradation and Conservation of Granitic Rocks in Monuments, Proceedings of the EC Workshop* (M. A. Vicente, J. Delgado-Rodrigues & J. Acevedo, eds): 295–300. Protection and Conservation of the European Cultural Heritage, Research Report No. 5. **SE** [86 taxa were identified from five dolmens and 20 rural churches in Spain.]

81. **Prieto, B., Rivas, M. T. & Silva, B. M. (1996)** Effectiveness of biocide treatments on granite. In *Degradation and Conservation of Granitic Rocks in Monuments, Proceedings of the EC Workshop* (M. A. Vicente, J. Delgado-Rodrigues & J. Acevedo, eds): 361–366. Protection and Conservation of the European Cultural Heritage, Research Report No. 5. **CM** [Four commercial biocides (Neodesogen, Paragon Invisible, Hyvar-X and Sanit-S), the cleaning agent B57 and two months of darkness were tested on granite colonized by lichens (genera *Parmelia*, *Lasallia*, *Pertusaria*, *Rhizocarpon* and *Aspicilia*) and algae. Neodesogen and B57 were the most effective, even after one year, and did not cause appreciable modification to the stone surface. Paragon Invisible was ineffective and caused a remarkable colour change.]

82. **Prieto, B., Rivas, T. & Silva, B. (1999)** Environmental factors affecting the distribution of lichens on granitic monuments in the Iberian Peninsula. *Lichenologist* **31:** 291–305. **LM, SE, PS** [The phytosociology of lichens colonizing 20 churches and 7 dolmens in NW Spain (Galicia) and in central Portugal was studied. A total of 78 and 30 species were identified from dolmens and churches, respectively. The sites clustered clearly into four easily defined groups. The most important factors influencing lichen growth are the class of structure (church or dolmen), pH, availability of nitrogen and moisture. Twenty one species considered representative of lichen colonization on granitic monuments are listed and considered potentially useful targets for testing the effectiveness of biocides.]

83. **Prieto, B., Rivas, T. & Silva, B. (2002)** Alteracion del granito por accion de los liquenes. Aspectos biogeofisicos y biogeoquimicos. In *Biodeterioro de Monumentos de Iberoamerica* (C. Saiz-Jimenez & H. A. Videla, eds): 125–147. Spain: CYTED. **LM, OX, PB, PC, PR, PS** [Biogeophysical and biogeochemical aspects of lichen action on granite are analysed on the basis of results of a study of more than 25 granite monuments in Galicia. Data are compared with those of other authors.]

84. **Prieto, B., Seaward, M. R. D., Edwards, H. G. M., Rivas, T. & Silva, B. (1999)** Biodeterioration of granite monuments by *Ochrolechia parella* (L.) Mass.: an FT Raman spectroscopic study. *Biospectroscopy* **5:** 53–59. **OX** [Production of calcium oxalate by *Ochrolechia parella* growing on granite rock from ancient monuments in and around Santiago de Compostela (NW Spain) were analyzed by FT Raman spectroscopy. The spectroscopic investigation shows that this lichen is an aggressive colonizer that can cause physico-chemical disturbances to granite, which partly depend on humidity conditions.]

85. **Prieto, B., Seaward, M. R. D., Edwards, H. G. M., Rivas, T. & Silva, B. (1999)** A Fourier transform-Raman spectroscopic study of gypsum neoformation by lichens growing on granitic rocks. *Spectrochimica Acta, Part A* **55:** 211–217. **PC** [The ability of lichens to catalyse the formation of gypsum from granite in the presence of low SO_4^{2-} has been demonstrated for various lichen species colonizing monuments in Galicia (NW Spain).]

86. **Prieto, B., Silva, B., Rivas, T., Wierzchos, J. & Ascaso, C. (1997)** Mineralogical transformation and neoformation in granite caused by the lichens *Tephromela atra* and *Ochrolechia parella*. *International Biodeterioration and Biodegradation* **40:** 193–199. **LM, OX, PC, PR, PS** [Micromorphological, mineralogical and chemical effects of *Tephromela atra* and *Ochrolechia parella* on the granite used in the construction of the Toxosoutos Monastery (Noia, north-west Spain) were studied using various analytical techniques. The lichens caused physical weathering of feldspar, biotite, and muscovite and entrapped the loosened mineral grains in their thalli. A significant depletion of potassium from biotite and its transformation into hydroxyaluminium-vermiculite, together with a neoformation of whewellite (in *O. parella*) and of calcium carbonate (in *T. atra*) are the most significant chemical weathering induced in granite by these lichens. Calcite formation is attributed to high pH conditions in the thalli, due to the release of sodium from plagioclase during weathering.]

87. **Prudon, T., Labine, C. & Flaherty, C. (1980)** Removing stains from masonry. In *The Holdhouse Journal Compendium*: 97–98. Woodstock: The Overlook Press. **CM** [The importance of selecting the appropriate solvent in cleaning stained masonry is

stressed. Techniques for the removal of different stains (iron, lichens, copper, oil, asphalt and tar, manganese, vanadium), with the recipes of the various poultices, are described.]

88. **Puertas, F., Blanco, M. T., Palomo, A., Ortega-Calvo, J. J., Ariño, X., & Saiz-Jimenez, C. (1995)** Characterization of mortar from Italica mosaics: causes of deterioration. In *Proceedings of the 5th Conference of the International Committee for the Conservation of Mosaics, Conimbriga*: 197–202. **LM** [The Roman mortars and present-day mortars used for repairs from the mosaics of Italica (Spain) were analysed and completely characterized. The ancient surfaces were colonized by lichens, cyanobacterial biofilms and mosses. Lichens usually completely cover the mortars giving them a resistance to external aggression such as rain, wind, and erosion. On the other hand moss rhizoids disaggregate the mortar.]

89. **Puertas, F., Blanco-Varela, M. T., Palomo, A., Ariño, X., Hoyos, M. & Saiz-Jimenez, C. (1995)** Causes and forms of decay of stuccos and concretes from the Roman city of Baelo Claudia (Southern Spain). In *Architectural Studies, Materials and Analysis* (C. A. Brebbia & B. Leftheris, eds) Structural Studies of Historical Buildings IV, **1:** 171–178. Computational Mechanics Publications. **BM, LM** [The stuccos and concretes from the Roman city of Baelo Claudia (South Spain) have been studied. XRD, ion chromatography, petrographic and SEM-EDX analyses were used to characterize the materials. Sunny and dry stucco surfaces supported xerophilous and nitrophilous lichens, while algae and cyanobacteria are restricted to cryptoendolithic growth. The surfaces of sheltered stuccos are dominated by communities of algae and cyanobacteria.]

90. **Raimondo F. M., Aiello P., Campisi P., Geraci A., Mannino M. & Merlo F. (1995)** Contributo alla conoscenza dei biodeteriogeni dei materiali lapidei in ambito urbano. *Quaderni di Botanica ambientale ed Applicata* **6:** 143–159. **BM** [Two historic buildings, located in the urban area of Palermo (S Italy), were studied in order to examine the biodeteriogenic agents and to find possible environmental bioindicators.]

91. **Robert, M., Vicente Hernandez, M. A., Molina Ballesteros, E. & Rives Arnau, V. (1993)** The role of biological factors in the degradation of stone and monuments. Alteracion de granitos y rocas afines, empleados como materiales de construccion: deterioro de monumentos historicos. In *Actas del workshop, Consejo Superior de Investigaciones Cientificas, Avila, Spain*: 103–115. Madrid: Consejo Superior de Investigaciones Cientificas. **BM** [The role of various organisms (bacteria, algae, fungi, lichens, roots) in rock weathering or monument biodeterioration is analyzed. All these organisms can establish very active weathering microsystems around them through several reactions: acid secretion, complex formation, and oxido-reductions. They induce both dissolution and precipitation processes.]

92. **Roccardi, A. & Piervittori, R. (1998)** The aerodiffused lichen-component: problems and methods. In *Abstract 6th International Congress on Aerobiology, Perugia, 31/8–5/9 1998*: 268. **BM** [Lichen propagules (both sexual and vegetative) have been examined, in an innovative way, as one of the possible biological components dispersed in the air.]

93. **Rodriguez-Hidalgo, J. M., Garcia-Rowe, J. & Saiz-Jimenez, C. (1994)** Mosaicos de Italica: ejemplos de deterioro. In *Mosaicos 5, Conservacion in situ, Palencia 1990, Excma*: 293–303. Palencia: Diputacion Provincial. **BM, LM** [Four mosaics in the Roman city of Italica (Spain) have been studied. The deterioration included the loss of tesserae due to the disintegration of mortars, poor adhesion between the different strata, chemical attack of vitreous tesserae, and colonization by lichens, mosses and vascular plants.]

94. **Romao, P., Pridêncio, M. I., Trindade, M. J., Nasraoui, M., Gouveia, M. A., Figueiredo, M. O. & Silva, T. (2000)** The Sao Sebastiao Church of Terceira island (Azores, Portugal)—Characterization of the stones and their biological colonisation. In *Proceedings of 9th International Congress on Deterioration and Conservation of Stone, Venice* (V. Fassina, ed.): 493–497. Amsterdam: Elsevier. **BM, LM** [The stone (tuff and trachyte) of São Sebastião Church (Azores, Portugal) was characterized by chemical and mineralogical analyses. Twenty four species of lichens were recognized and their ecological variability discussed. Bacteria, fungi, algae and mosses were also present but less frequent.]

95. **Rooney-Dawn, F. (1994)** Cambodia: the condition of the temples at Angkor in 1993. *Newsletter (Oriental Ceramic Society)* **2:** 8–9. **BM** [The poor condition of the temples has resulted from exposure to monsoon rains, with the consequent overgrowth of lichens, moss, algae, and tree roots, as well as from neglect, especially with regard to the unstable structures, from warfare, and from theft.]

96. **Rosato, V. G., Traversa, L. & Cabello, M. N. (2000)** The action of *Caloplaca citrina* on concrete surfaces: a preliminary study. In *Proceedings of the 9th International Congress on Deterioration and Conservation of Stone* (V. Fassina, ed): 507–511. Amsterdam: Elsevier. **PC, OX** [Chemical action of *Caloplaca citrina* and the modifications induced in the substratum composition are examined.]

97. **Russell, N. C., Edwards, H. G. M. & Wynn-Williams, D. D. (1998)** FT-Raman spectroscopic analysis of endolithic microbial communities from Beacon sandstone in Victoria Land, Antarctica. *Antarctic Science* **10:** 63–74. **PC, OX** [Antarctic cryptoendolithic microbial communities, including hyaline lichen zones, are examined by Laser-based Fourier-Transform Raman spectroscopy (FTRS) to identify *in situ* the compounds of ecophysiological significance.]

98. **Saiz-Jimenez, C. & Ariño, X. (1995)** Colonizacion biologica y deterioro de morteros por organismos fototrofos. *Materiales de Construccion* **45**(240): 5–16. **BM, LM** [Mortars of the Roman towns of Italica and Baelo Claudia (Spain) have been colonized by many phototrophic organisms.

Cyanobacteria, algae, lichens, mosses and vascular plants have been identified and biodeterioration processes caused by them are investigated and discussed. Mortar is considered one of the most bioreceptive materials.]

99. **Saiz-Jimenez, C. (1984)** Weathering and colonization of limestones in an urban environment. In *Soil Biology and Conservation of the Biosphere* (J. Szegi, ed.): 65–71. Budapest: Akademiai Kiado, Publishing House of the Hungarian Academy of Sciences. **BM, LM, PR** [The limestone of the Giralda tower (Seville, Spain) is weathered by abiotic and biotic agents, mainly atmospheric pollutants and lichens. Actinomycetes, fungi, algae, mosses, and higher plants are also present.]

100. **Saiz-Jimenez, C. (1990)** The mosaics of Italica. A natural laboratory of stone colonization. *European Cultural Heritage, Newsletter on Research* **4:** 34–38. **LM** [A short note summarizing investigations on various colonization strategies of lichens on mosaics of Italica (Spain).]

101. **Saiz-Jimenez, C. (1991)** Deterioro de materiales petreos por microorganismos. In *Jornadas Restauracion y Conservacion de Monumentos*: 31–39. Madrid: Instituto de Conservacion y Restauracion de Bienes Culturales. **BM** [The morphology of deterioration of stone monuments is described together with the different groups of organisms growing on them, their ecological requirements, and the decay proccesses induced.]

102. **Saiz-Jimenez, C. (1994)** Biodeterioration of stone in historic building and monuments. In *Biodeterioration Research 4. Mycotoxin, Wood decay, Plant Stress, Biocorrosion, and General Biodeterioration* (G. C. Llewellyn, W. V. Dashek & C. E. O'Rear, eds): 587–604. New York: Plenum. **BM, LM** [The role played by biological activity in deterioration of monuments is discussed. A review is provided of biodeterioration caused by bacteria, fungi, cyanobacteria, algae, lichens, bryophytes, and vascular plants.]

103. **Saiz-Jimenez, C. (1999)** Biogeochemistry of weathering processes in monuments. *Geomicrobiology Journal* **16:** 27–37. **BM, LM, OX** [Some case studies in polluted (the cathedral of Seville), rural (Roman town of Baelo Claudia) and hypogean environments (Roman necropolis of Carmona and Tito Bustillo Cave) are presented. In the urban environment gypsum and polycyclic aromatic hydrocarbons can be used by cyanobacteria and heterotrophic bacteria respectively. In hypogean environments calcifying cyanobacteria mobilize calcium from the substratum. In rural environments stones and mortars are altered by cyanobacteria, algae and lichens; in some cases the last group confers protection to surfaces.]

104. **Saiz-Jimenez, C., Grimalt, J., Garcia-Rowe, J. & Ortega-Calvo, J. J. (1991)** Analytical pyrolysis of lichen thalli. *Symbiosis* **11:** 313–326. **PC, LM** [Samples of *Lecanora muralis* from polluted (cathedral of Seville) and non-polluted areas were studied by means of pyrolysis-gas chromatography and pyrolysis-gas-chromatography-mass spectrometry. A complex mixture of compounds, characteristic of petroleum contamination, is present in the sample from Seville. In addition, dehydration products from hopanediols and hopanetriols were found.]

105. **Salvadori, O. (2002)** Lichens and deterioration of stone: progress and problems. In *Art, Biology, and Conservation—Biodeterioration of Works of Art, Symposium, New York, June 2002*: 69–73. New York: The Metropolitan Museum of Art. **CM, LM, OX** [The effects of epilithic and endolithic lichens on stone, the different aspects awaiting further investigations and treatments used to remove lichens from monuments are summarized. The possible protective action of lichens and their role in the production of oxalate patina are discussed.]

106. **Salvadori O. & Tretiach M. (2002)** Thallus-substratum relationships of silicicolous lichens occurring on carbonatic rocks of the Mediterranean region. In *Progress and Problems in Lichenology at the Turn of the Millenium Bibliotheca Lichenologica* (X. Llimona, H. T. Lumbsch & S. Ott, eds): 57–64. Berlin, Stuttgart: J. Cramer. **EP, OX, PR, PS** [The penetration into the substratum of 40 specimens (*Diploschistes actinostomus*, *Lecanora sulphurea* and *Tephromela atra*), the kind and distribution of biomineralogical products were studied with different techniques. Calcium oxalate is generally detected in thalli growing on both calcareous and siliceous rocks, but in different amounts. The results suggest a very wide ecological tolerance of substratum by these lichen species.]

107. **Salvadori, O., Appolonia, L. & Tretiach, M. (2002)** Thallus-substratum relationships of silicicolous lichens occurring on carbonatic rocks of the Mediterranean regions. In *The Fourth IAL Symposium, Progress and Problems in Lichenology at the Turn of the Millennium. Book of Abstracts*: 34. Barcelona: Universitat de Barcelona. **OX, PR, PS** [Thallus-substratum relationships were studied in three epilithic lichens (*Diploschistes actinostomus*, *Lecanora sulphurea* and *Tephromela atra*) from siliceous and carbonatic rocks. Calcium oxalate is generally detected in thalli growing on both calcareous and siliceous rocks, but in different quantities. The species studied had a very wide ecological tolerance of substratum.]

108. **Salvadori, O., Pinna, D. & Grillini, G. C. (1994)** Lichen-induced deterioration on an ignimbrite of the Vulsini complex (Central Italy). In *Lavas and Volcanic Tuffs, Proceedings of the International Meeting, Easter Island, Chile* (A. E Charola, R. J. Koestler & G. Lombardi, eds): 143–154. Roma: ICCROM. **OX, PR** [Observations of thin sections, electron microprobe and x-ray diffraction analysis have led to the identification and localization of weathering products formed by eight crustose and one foliose lichen species growing on volcanic tuffs. The species can form and store in the thalli different quantities of weddellite removing calcium from the substratum. Penetration of fungal hyphae is relevant and it can cause the detachment of particles of stone.]

109. **Sanna M.S. (1999)** Biodeteriogeni vegetali rilevati nel complesso monumentale di San Placido

Calonerò (Messina). *Quaderni di Botanica ambientale ed Applicata* **10:** 81–91. **BM** [The biodeteriogenic agents (54 tracheophytes, 2 mosses, 8 lichen taxa) which can affect the structural stability of buildings in the St Placido Calonerò monumental complex (Italy, Sicily) are studied.]

110. **Seaward, M. R. D., Edwards, H. G. M. & Farwell, D. W. (1998)** Fourier-transform Raman spectroscopy of the apothecia of *Chroodiscus megalophthalmus* (Müll. Arg.) Vězda & Kantvilas. *Nova Hedwigia* **66:** 463–472. **OX** [A study of calcium oxalate distribution. It is tentatively suggested that calcium oxalate has a metabolic role in regulating water within the thallus and as a deterrent to grazing invertebrates.]

111. **Seaward, M. R. D. & Edwards, H. G. M. (1995)** Lichen-substratum interface studies, with particular reference to Raman spectroscopic analysis. 1. Deterioration of works of art by *Dirina massiliensis* forma *sorediata*. *Cryptogamic Botany* **5:** 282–287. **OX, PC, PR** [The results of Raman spectroscopic analysis application in the study of deterioration caused by *Dirina massiliensis* f. *sorediata* on frescoes at Palazzo Farnese, Caprarola (Italy) are presented. Oxalate was detected in thalli and within the substratum. Particulate matter incorporated in thalli has been identified, and features in the spectra ascribed to metabolic by-products are reported.]

112. **Seaward, M. R. D. & Edwards, H. G. M. (1997)** Biological origin of major chemical disturbances on ecclesiastical architecture studied by Fourier transform Raman spectroscopy. *Journal of Raman Spectroscopy* **28:** 691–696. **LM, BM** [Lichens, formerly considered as weathering agents in a geological context, are shown to be capable of biodeteriorating stone substrata within a relatively short time-scale. Research on *Dirina massiliensis* f. *sorediata* is presented.]

113. **Seaward, M. R. D., Giacobini, C., Giuliani, M. R. & Roccardi, A. (2001)** The role of lichens in the biodeterioration of ancient monuments with particular reference to Central Italy (Reprinted). *International Biodeterioration and Biodegradation* **48:** 202–208. **LM, CM** [A synthesis is provided of work carried out in Central Italy on a wide range of archaeological materials, both outdoors and indoors. Relationships between lichens and substrata are studied to identify species potentially harmful in biodeterioration processes.]

114. **Seaward, M. R. D. (1997)** Major impacts made by lichens in biodeterioration processes. *International Biodeterioration and Biodegradation* **40:** 269–273. **GE, SE, LM, OX, PR, PS** [The role of lichens in pedogenesis in a geological context and in biodeterioration of historic monuments over a relatively short period of time is discussed, with particular attention to the strong deterioration caused by *Dirina massiliensis* f. *sorediata* on ancient stonework. The relationship with some ecological factors and the applications of remote sensing are considered].

115. **Silva, B., Prieto, B., Rivas, T., Sanchez-Biezma, M. J., Paz, J. & Carballal, R. (1997)** Rapid biological colonization of a granitic building by lichens. *International Biodeterioration and Biodegradation* **40:** 263–267. **BM, LM, PR** [The deterioration of a modern granite building, the Galician Centre of Contemporary Art (Santiago de Compostela, Spain) completed in 1993, is studied. Colonization by lichens, *Chlorophyceae*, hyphomycetes and mosses do not seem to contribute greatly to the rock deterioration over a short time-scale, since the raw granite was already severely weathered. *Trapelia coarctata* and *T. involuta* are the most abundant lichens and the first colonizers of the wall. Granite blackening is attributed chiefly to the presence of microorganisms or their remains.]

116. **Silva, B., Rivas, T. & Prieto, B. (1999)** Effects of lichens on the geochemical weathering of granitic rocks. *Chemosphere* **39:** 379–388. **PB, PS, PR** [The weathering effects of lichens on granitic rocks have been evaluated from a geochemical standpoint. Several lichens, representing a nucleus of species colonizing buildings and monuments of Galicia (NW Spain), were studied. Lichens appear to protect the exposed rock surface from atmospheric weathering, especially leaching, thereby reducing loss of the most mobile elements. Various lichen species had similar effects on weathering. The term 'intephase' is introduced to describe rock engulfed in lichen thalli].

117. **Souza-Egipsy, V., Wierzchos, J., García-Ramos, J. V. & Ascaso, C. (2002)** Chemical and ultrastructural features of the lichen-volcanic/sedimentary rock interface in a semiarid region (Almería, Spain). *Lichenologist* **34:** 155–167. **PR, PS, PB, PC, OX** [Chemical and ultrastructural features of the interface formed by *Diploschistes diacapsis*, *Neofuscelia pulla* and *Xanthoria parietina* with the rock surfaces are examined.]

118. **Spier, L., Sparrius, L., van Herk, K. & Aptroot, A (2000)** Excursie naar het Fort Abcoude op 12 februari 2000. *Buxbaumiella* **51:** 45–49. **LM** [A list of 89 lichens collected during a field trip to Fort Abcoude, an old fortification, is presented. The substrata analyzed include concrete, iron, brick, and asbestos.]

119. **Terrón Alfonso, A., Barquín, P. & Marcos, R. (2000)** Alteration analysis of the lichen-rock interface in San Isidoro of Leon (Spain). In *The Fourth IAL Symposium, Progress and Problems in Lichenology at the Turn of the Millennium. Book of Abstracts*: 112. Barcelona: Universitat de Barcelona. **PS, PB** [Rock surface alterations are shown by microanalytical techniques to identify chemical changes affecting the lichen-rock inteface.]

120. **Tiano, P. (1998)** Biodeterioration of monumental rocks: decay mechanisms and control methods. *Science and Technology for Cultural Heritage* 7(2)**:** 19–38. **BM, CM** [Bioreceptivity of stone, ecological succession and decay mechanisms of bacteria, algae, lichens, fungi, plants and animals are reviewed. The most useful methods to classify and study organisms involved in biodeterioration and methodologies of intervention for their elimination or control are discussed.]

121. **Torres Montes, L., Alvarez Gasca, D., Reyes, M., Hernandez Rivero, J., Charola, A. E., Koestler, R. J. & Lombardi, G. (1994)** The Cuauhcalli—a monolithic Aztec temple at Malinalco, Mexico: deterioration and conservation problems. In *Lavas and Volcanic Tuffs: Proceedings of the International Meeting, Easter Island, Chile, 25–31 October, 1990*: 63–72. Rome: ICCROM. **BM** [The deterioration of stone, a basaltic tuff, is mainly caused by infiltration of water which hydrolyzes certain minerals thus increasing the stone porosity. Lichens, as well as other microorganisms, are found on the monuments. Conservation measures and the effectiveness of applied treatments are discussed.]

122. **Traversa, L. P., Rosato, V. & Vitalone, C. (1999)** Colonizacion biologica en costrucciones de valor historico. In *V Congreso Iberoamericano de Patologia de las Costrucciones VII Congreso de Control de Calidad, Montevideo*: 1575–1580. **LM** [Lichen growth on several monuments in Buenos Aires Province and its action on the substratum were studied. The environmental conditions and the characteristics of the structural elements supporting the biological growth are analyzed.]

123. **Traversa, L. P., Rosato, V., Pittori, C. A. & Zicarelli, S. (2001)** Biological studies on a concrete dam. *Materials and Structures* **34**(242)**:** 502–505. **PS, OX** [Effects of lichen colonization on cement are discussed.]

124. **Upreti, D. K. (1994)** Indian lichenology in 1993. *British Lichen Society Bulletin* **74:** 16–18. **LM** [News about movement of the Lucknow University lichen collections (LWU) and Herb. Awasthi to the National Botanical Research Institute (LWG), and study of lichens on Indian monuments.]

125. **Viles, H. (1995)** Ecological perspectives on rock surface weathering: towards a conceptual model. *Geomorphology* **13:** 21–35. **PS, SE** [A review of the different weathering capacities of a range of microorganisms and lichens, and their role in weathering in particular locations. A simple preliminary conceptual model of biological weathering and geomorphology is presented relating biological weathering activity to an environmental stress gradient].

126. **Wakefield, R. D. & Jones, M. S. (1998)** An introduction to stone colonizing micro-organisms and biodeterioration of building stone. *Journal of Engineering Geology* **31:** 301–313. **BM, LM, RV** [An overview of the principal mechanisms involved in stone deterioration. Weathering induced by the principal groups of microrganisms including lichens is reviewed.]

127. **Warscheid, Th. & Braams, J. (2000)** Biodeterioration of stone: a review. *International Biodeterioration and Biodegradation* **46:** 343–368. **BM, RV** [A comprehensive and up to date review of stone biodeterioration including bioreceptivity and microecology of building stones, biogeochemical and biogeophysical deterioration mechanisms, methods for the identification of biodeterioration of stones *in situ* and in the laboratory, and methods for the prevention and control of biodeterioration.]

128. **Wendler, E. & Prasartset, C. (1999)** Lichen growth on old Khmer-style sandstone monuments in Thailand: damage factor of shelter? In *Proceedings of the 12th Triennal Meeting of the ICOM Committee for Conservation* **2:** 750–754. Lyon. **LM, EP, PR** [Four Khmer sandstone monuments have been investigated to determine if lichens are harmful or have protective functions. Deterioration seemed less in lichen covered than lichen-free areas. Drill resistance measurements were carried out on areas with many lichens and on lichen-free stone to obtain a stregth depth profile. In addition, rates of respiration and photosynthesis were measured. Lichens caused detachment of surface layers of 1 to 2 mm depth, but they protect the substratum by reducing the intensity of hygric changes. The removal of lichens should be discouraged.]

129. **Wessels, D. & Wessels, L. (1995)** Biogenic weathering and microclimate of Clarence sandstone in South Africa. *Cryptogamic Botany* **5:** 288–298. **SE, EP, PR, PS** [Colonization and growth of *Lecidea* aff. *sarcogynoides* on Clarens sandstone in South Africa were studied and its weathering rate over 43 years was calculated. Macro- and microclimatic parameters (air and sandstone temperatures, RH of the air and in the sandstone, solar radiation on the sandstone, thallus wetness and wind speed) were measured and related to the growth of endolithic lichens.]

130. **Wierzchos, J. & Ascaso, C. (1998)** Mineralogical transformation of bioweathered granitic biotite, studied by HRTEM: evidence for a new pathway in lichen activity. *Clays and Clay Minerals* **46:** 446–452. **PR, PS** [Unaffected granitic biotite, and bioweathered material from the granitic biotite and the *Parmelia conspersa* lichen thallus interface, were examined using HRTEM and ultrathin sectioning. Biophysical exfoliation processes and interlayer ionic exchange of K and subsequent vermiculite phase formation are the processes responsible for bioweathering of biotite induced by lichens.]

131. **Wilson, M. J. (1995)** Interactions between lichens and rocks; a review. *Cryptogamic Botany* **5:** 299–305. **LM, OX, PB, PC, PR, PS, RV** [Review over the period 1976–1992 of lichen-rock interactions. The necessity for interdisciplinary investigations and the complementary use of different techniques are stressed. Lichen weathering of mineral surfaces and related mechanisms, biomineralization products (iron oxides, clay minerals, oxalates), and the role of lichen acids are summarized.]

132. **Zagari, M., Antonelli, F. & Urzì, C. (2000)** Biological patinas on the limestones of the Loches Romanic tower (Touraine, France). In *Proceedings of 9th Internatinal Congress on Deterioration and Conservation of Stone, Venice 19–24 June 2000* (V. Fassina, ed.): 445–451. Amsterdam: Elsevier. **LM, OX** [The porous siliceous limestone showed scaling, alveolization, detachment and colour change to yellow and/or orange where a biological patina was present. Lichens and a phototrophic microflora covered almost all the N-facing walls. The occurrence of calcium oxalate (weddellite) was always associated with intense

colonization by lichens, mainly *Dirina massiliensis*. Other lichen species could have a protective effect on the substratum. Colour changes of limestone could be due to bacteria and fungi.]

Analytical Index

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