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Diversity and distribution of lichens on some major monuments of Madhya Pradesh, India

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The paper deals with the occurence of 95 species of lichens belonging to 33 genera, 16 families and 1 genus to class Imperfectii growing on some major monuments of Madhya Pradesh. The members of the lichen family Physciaceae dominate the monuments as represented by 24 species, followed by members of Teloschistacese and Verrucariaceae. The crustose form of lichens exhibit their luxuriant growth, followed by squamulose and leprose forms on various monuments. Out of the different substrates the sandstone bears the maximum diversity of lichens represented by 50 species, followed by siliceous, bauxite and calcareous substrates represented by 33, 5 and 4 species, respectively. Observation of the damage caused by the metal complexing activity of some common lichen products is also discussed.

Key- words–Lichen distribution, Monuments, Biodeterioration, Madhya Pradesh.

INTRODUCTION

LICHENS have ability to grow on a variety of substrates under a wide range of environmental conditions. They play an important role in process of pedogenesis due to geophysical and geochemical weathering. Lichens are the first living things to occupy newly exposed rock surface (Chen *et al.*, 2000). A large number of biodeterioration studies of lichens from different European countries are available (Ascaso *et al.*, 1976, Bech-Anderson & Christensen 1983, Danin *et al.*, 1983, Jones & Wilson 1985, Saiz- Jimenez 1981). Recently, Piervittori *et al.*, (2004) listed more than 600 references on lichens and monuments all over the world. However, in Indian context only a few studies on the lichens growing on different monuments of the country are available. Chatterjee *et al.*, (1995) listed the lichens from some monuments of Karnataka and Orissa. Singh and Upreti (1991) studied the lichen flora of Lucknow with special reference to its historical monuments. Upreti (2002) recorded 14 lichen species growing on the Khajuraho temple and nearby area. Ayub (2005) and Bajpai (2007) listed lichens growing on some major monuments of Uttar Pradesh and rock shelters of Bhimbetka World Heritage zone, Madhya Pradesh, respectively.

Madhya Pradesh is one of the culturally rich states of India, bestowed with three world heritage zones and more than 600 ancient monuments, of which, 50 are protected. Most of the monuments in the state are constructed of either coarse granite, sandstone or bricks (Lakhori) and plastered with lime plaster or cement, which provide an excellent substrate for a large number of lichens to colonize together with other groups of plants. The calcicolous (lime loving) lichens which prefer to grow mostly on monuments and historical buildings are unique as they have an in-built tolerance against the effect of acidic gases present in the atmosphere. Except a few biodeterioration studies on monuments of Madhya Pradesh, a large number of monuments of this state are not explored for their lichen diversity. Thus, in the present study an attempt has been made to assess the diversity of lichens colonizing on monuments of Madhya Pradesh and their biodeterioration effect on them.

MATERIAL AND METHODS

The study is based on the collection of lichens from more than 30 monuments situated in seven districts of Madhya Pradesh (Table-1). More than 500 lichen specimens were collected directly from abandoned monuments or nearby area of the monuments during January 2007. As most of the monuments are protected, and looked after by the Archaeological Survey of India (ASI), it was not possible to collect the lichen samples directly from the monuments. To

Table 1–Localities surveyed for collection of lichens.

S. No.	District	Monuments
1	Anoopur	Patleshwer temple, Jwaleshwar temple, Kapildhara, Kabirchabutra.
2	Dhar	Dhar fort, Lat ki masjid, Bhoj shala, Lal mahal, Bhangi gate, Jali mahal, Alamgir gate, Jami masjid, Delhi gate, Jahagir mahal, Sun set point, Lohani cave, Rani roopmati mahal, Chistikhan mahal.
3	Dindori	Khurkhuri dader, Near Kabir
4	Hosangabad	Jatashankar temple, Apsarabihar, Chote mahadev, Pandav cave, Down fall.
5	Jabalpur	Madan mahal, Karia pathar
6	Raisen	Rang mahal, Main cave of Bhimbetka, Jamunjhiri, Lakhajwar.
7	Tikamgarh	Sheesh mahal, Jehangir mahal.

avoid the destruction of protected monuments, lichen samples from the abandoned monuments, or nearby rocks were selected for collection. Lichen specimens collected from nearby rocks of the monuments in the past and preserved in the herbarium of National Botanical Research Institute, Lucknow (LWG) were also included for this study.

Morphology of the lichen specimens was studied using stereozoom binocular microscope. The anatomical details of thallus and fruiting bodies were studied in free hand sections mounted in water under compound microscope. Chemistry of the specimens was studied following Walker and James (1980). The colour spot tests were carried out on cortex and medulla with the usual chemical reagents such as aqueous potassium hydroxide (K), *Para-* phenylenediamine (P) and aqueous calcium hypochlorite (C). Thin layer chromatography was performed for authentic identification of the lichen substances in solvent system A.

RESULTS AND DISCUSSION

The study revealed occurrence of the 95 species belonging to 33 genera and 16 families and 1 genus to class Imperfectii on the monuments or nearby rocks in the seven districts of Madhya Pradesh. Out of the 16 families of lichens, members of family Physciaceae exhibit their dominance followed by members of families Teloschistaceae, Verrucariceae, Collemataceae and Lecanoraceae (Table-2). The probable reason for the luxuriant growth of Physciaceae lichens on monuments may be their adaptation mechanisms developed by these lichens against metalliferous environment (DeWitt, 1976). More than 47 crustose lichen dominate most of the localities followed by foliose, squamulose and leprose forms represented by 28, 16 and 4 species, respectively. The monuments and rocks in Hosangabad District exhibit the dominance of crustose lichens. The foliose, squamulose and leprose lichens were common in Rasien and Dhar districts (Table-3; Plate 1 & 2). The reason for luxuriant growth of crustose lichens on monuments may be due to their tolerance to the air pollution followed by foliose and fruticose forms (Gilbert, 1973). The monuments in Raisen District exhibit the maximum dominance of lichens represented by 43 species followed by Hosangabad, Dhar and Anoopur districts represented by 36, 29 and 28 species, respectively. The most common lichen genera growing on different monuments are *Buellia, Caloplaca, Lecanora, Diploschistes, Endocarpon* and *Peltula.* Monuments with sandstone as the construction material bears the luxuriant growth of lichens, followed by siliceous, bauxite, calcareous and quartz.

The most common species on monuments of Hosangabad District belong to the lichen genera *Lecanora, Parmotrema, Buellia,* and *Heterodermia*. A total of 36 species of 20 genera belonging to 14 families of lichens are recorded from the area and sandstone rock bear the maximum growth of lichens. The Dhar District has 29 species belonging to 19 genera and 12 families of lichens. A total of 28 species belonging to 19 genera and 13 families are recorded from Anoopur District. In Anoopur the bauxite rocks are the major construction material for monuments, bears growth of 19 species followed by 5 species on sandstone and 2 on lime plaster, and a single species on brick; the common genera are *Leptogium, Heterodermia* and *Lecanora*. The districts of Dindori, Jabalpur and Tikamgarh exhibit poor diversity of lichens as both Dindori and Jabalpur represent the occurrence of 14 and 8 species, respectively. The area shows growth of the species of *Buellia, Dirinaria, Caloplaca, Heterodermia, Endocarpon* and *Peltula* on bauxite, sandstone and siliceous rocks. The Bhimbetka rock shelters in Raisen District have exposed sandstone rocks which showed luxuriant growth of 42 species of lichens belonging to 17 genera and 11 families. The species of *Caloplaca, Diploschistes, Endocarpon, Peltula , Phylliscum,* are the dominant species of the area (Bajpai, 2007).

The foliose and fruticose lichens are less effective biodeteriorant as they are loosely attached to the substratum or may be attached through a single or few points through holdfast or rhizines. The crustose and squamulose lichens are more effective deteriorant of the rock because they are adpressed to the substratum with their whole lower surface. The squamulose lichen taxa, during dry condition, exhibit slightly upward curved margins. Numerous particles of the substratum adhered on their lower surface are also removed from this action. The curling action of margin thus seems to be the result of the well documented pulling action of lichen thallus when it dries up. On receiving moisture the squamules or thallus expands and margin gets flattened and attach to the substrates once again.

The lichen growth on monuments depends on a number of factors, viz., climatic conditions, the dispersal of lichen diaspores, environmental pollution, nature of substratum, texture of rocks, rock porosity, water holding capacity of rock, chemical composition and architectural designs of the monuments.

The water holding capacity of rocks play important role in the colonization of lichens. Leprose powdery lichens *Lepraria* and crustose genera *Buellia, Cryptothecia* have very thick medulla, *Rinodina* and *Staurothele* with thin medullary crust over rock require less water, while, foliose and squamulose species of *Caloplaca, Endocarpon, Phylliscum, Parmotrema* and *Pyxine* grow on rocks having high water intake capacity and high rock porosity too. The sandstone and calcareous rocks having high water holding capacity exhibit more growth of lichens than the bauxite rocks.

Most of the chemical substances are derived through acetate-polymalonate pathway of secondary lichen products and have a metal complexing property due to their polar group (-CHO,- COOH, or –OH). The presence of the donar group in adjacent (ortho) position in the molecular structure of many lichen substances provides them metal complexing property,

Table 2–Distribution of lichens on some major monuments of Madhya Pradesh

S. No.	Name of Species	Forms	Number of sites studied							Substratum	Secondary substances
			1	2	3	4	5	6	7		
1	**Arthoniaceae**										
	Cryptothecia lunulata (Zahlbr.) Makh. & Patw.	Crustose				2				Sandstone	Gyrophoric, barbatic acid
	Chrysopsora sp.-1	Crustose						1		Siliceous	Atranorin
	Chrysopsora sp.-2	Crustose						2		Sandstone	No chemicals
	Chrysopsora sp.-3	Crustose						1		Sandstone	Gryophoric
	Helminthocarpon cherrapunjense Awasthi & Singh	Foliose				2				Sandstone	Atranorin, zeorin
2	**Bacidiaceae**										
	Bacidia arnoldiana Körb.	Crustose	2							Sandstone	No chemicals
	Lecania umbraticula (Nyl.) Smith	Crustose							1	bauxite	No chemicals
	Tephromela atra (Huds.) Hafellner	Crustose			1	1				bauxite	No chemicals
3	**Catillariaceae**										
	Catillaria nilgiriensis Pant & Awasthi	Squamulose					1			Siliceous	No chemicals
4	**Cladoniaceae**										
	Cladonia praetermissa Archer	Foliose	1							Siliceous	Atranorin, fumarprotocetric, protocetraric, psoromic
5	**Collemataceae**										
	Collema coilocarpum (Müll. Arg.) Zahlbr.	Foliose	2							Sandstone	No chemicals
	C. crispum (Huds.) Weber ex Wigg.	Foliose		8						Sandstone	No chemicals
	C. texanum Tuck.	Foliose						1		Siliceous	No chemicals
	Leptogium chloromelum (Swartz ex Ach.) Nyl.	Foliose	2							Siliceous	No chemicals
	L. denticulatum Nyl.	Foliose				2				Sandstone	No chemicals
	L. phyllocarpum (Pers.) Mont.	Foliose	2		1					Sandstone	No chemicals
	L. ulvaceum (Pers.) Vainio	Foliose	2							Sandstone	No chemicals
6	**Lecanoraceae**										
	Lecanora hensseniae Vänska	Crustose				2				Siliceous	Atranorin, caperatic, zeorin
	L. indica (Stirton) Zahlbr.	Crustose				2				Sandstone	Usnic acid, zeorin
	L. pseudostera Nyl.	Crustose	2				1			Sandstone	Atranorin, methyl perlatolic
	L. subimmersa (Fée) Vainio	Crustose				3				Siliceous	Atranorin, leoidin
	L. sulphurescens Fée	Crustose	2	3		3	2			Sandstone	Atranorin, gangloiden
	Lecanora sp.	Crustose				2		2		Siliceous	Atranorin,
	Lecanora sterile	Leprose		4						Calcarious	Atranorin, usnic, zeorin, salazinic
7	**Lichinaceae**										
	Phylliscum indicum Upreti	Squamulose	2	7				2	2	Sandstone	No chemicals
	P. testudineum Henssen	Squamulose						2		Sandstone	No chemicals
8	**Parmeliaceae**										
	Parmotrema praesorediosum (Nyl.) Hale	Foliose	1	8		3	2	3		Sandstone	Atranorin, chloroatranorin, parasorediosic
	P. grayanum (Hue) Hale	Foliose				2				Sandstone	Atranorin, parasorediosic
	P. tinctorum (Nyl.) Hale	Foliose				2				Sandstone	Atranorin, chloroatranorin
	Xanthoparmelia congensis (Stein) Hale	Foliose				2				Siliceous	Norstictic, usnic, stictic
	X. pseudocongensis Hale	Foliose	1			3				Siliceous	Norstictic, usnic, stictic
9	**Peltulaceae**										
	Peltula euploca (Ach.) Poelt ex Pisut	Squamulose	2	13	1	2	1	3	2	Sandstone	No chemicals
	P. obscurans (Nyl.) Gyelink	Squamulose		1			1	3	1	Sandstone	No chemicals
	P. patellata (Bagl.) Swinsow & Krog	Squamulose		8				4	2	Sandstone	No chemicals
	P. tortuosa (Nees) Wetm.	Squamulose		2				2		Siliceous	No chemicals
	P. zahlbruckneri (Hasse) Wetm.	Squamulose						2		Siliceous	No chemicals
10	**Pertusariaceae**										
	Pertusaria coccodes (Ach.) Nyl.	Crustose				2				Siliceous	Atranorin
	P. indica Srivastava & Awasthi	Crustose				4				Siliceous	Atranorin, perlatolic
	P. kodaikanalensis Choisy	Crustose				2				Siliceous	No chemicals
	P. leucosora Nyl.	Crustose				3				Siliceous	Atranorin
11	**Physciaceae**										
	Buellia ceylonensis Zahlbr. in Zahlbr. & Rechinger	Crustose					1			Sandstone	Norstictic
	B. disjecta Zahlbr.	Crustose		1			1	2		Sandstone	Atranorin
	B. hemisphaerica Singh & Awasthi.	Crustose				1				Sandstone	Norsticite, lichenoxanthone
	B. posthabita (Nyl.) Zahlbr.	Crustose						2		Calcareous	Atranorin
	B. stigmea Tuck.	Crustose				3	1			Sandstone	Norsticite

1. Anoopur 2. Dhar 3. Dindori 4. Hosangabad 5. Jabalpur 6. Raisen 7. Tikamgarh

	B. substigmea Singh & Awasthi	Crustose		1		2				Sandstone	Atranorin, stictic
	B. quartziana Singh & Awasthi	Crustose				1				Quartz	Atranorin
	Dimelaena thysanota (Tuck.) Hale & Culb.	Crustose						2		Calcareous	Lecanoric acid
	Dirinaria aegialita (Afz. in Ach.) Moore	Foliose						3		Siliceous	Divarcatic
	D. applanata (Fée) Awasthi	Foliose	1	2	1	2	1	2	1	Siliceous	Divarcatic
	D. confluens (Fr.) Awasthi	Foliose		2			1	3		Cement plaster	Atranorin, Divarcatic
	D. consimilis (Stirton) Awasthi	Foliose		3				1		Sandstone	Atranorin, Sekikaic acid
	Heterodermia diademata (Tayl.) Awasthi	Foliose	1			2				Sandstone	Atranorin, zeorin
	H. dissecta (Kurok.) Awasthi	Foliose	2			2				Sandstone	Norstictic, salazinic
	H. pseudospeciosa (Kurok.) Culb.	Foliose	2		1					Sandstone	Atranorin, norstictic, zeorin, salazinic
	H. speciosa (Wulfen) Trevisan	Foliose	2		1					Sandstone	Atranorin, norstictic, zeorin, triterpins
	Phaeophyscia hispidula (Ach.) Essl.	Foliose		9	1			1		Siliceous	Zeorin
	Physcia dilatata Nyl.	Foliose						2		Sandstone	Atranorin, zeorin
	P. dimidiata (Arn.) Nyl.	Foliose					2	2		Sandstone	Atranorin
	P. tribacoides Nyl.	Foliose	2	3						Sandstone	Atranorin
	Pyxine petricola Nyl. in Crombie	Foliose						2		Siliceous	Lichenoxanthone, triterpins
	P. subcinerea Stirton	Foliose				3				Siliceous	Lichenoxanthone, triterpins
	Rinodina oxydata (Massal.) Massal.	Crustose			2			3		Siliceous	Atranorin
12	**Teloschistaceae**										
	Caloplaca amarkantkana Joshi & Upreti	Crustose	1		1					Sandstone	Parietin
	C. awasthii Joshi & Upreti	Squamulose						3		Siliceous	Parietin
	C. cinnabarina (Ach.) Zahlbr.	Crustose						2		Siliceous	Atranorin, parietin
	C. cupulifera (Vainio) Zahlbr.	Crustose			1			3		Sandstone	Parietin
	C. decipiens (Arnold) Blomb. & Forss.	Crustose		7						Sandstone	Parietin
	C. subpoliotera Joshi & Upreti	Crustose						2		Sandstone	Atranorin
	C. subsoluta (Nyl.) Zahlbr.	Crustose		10				1		Sandstone	Parietin
	C. hueana de Lesd.	Squamulose				1				Sandstone	Atranorin
	C. chalybaea (Fr.) Müll. Arg.	Crustose	1			1				Siliceous	Parietin
	C. tropica Joshi & Upreti	Squamulose						1		Siliceous	Parietin
	Caloplaca Sp.1	Crustose						3		Sandstone	Parietin
	Caloplaca Sp.2	Crustose	2							Sandstone	Parietin
	Caloplaca Sp. 3	Crustose		4						Sandstone	Atranorin, parietin
13	**Thelotremataceae**										
	Diploschistes caesioplumbeus (Nyl.) Vainio	Crustose						2		Calcareous	Lecanoric, diploschistic, orsellic
	D. candidissimus (Krempelh.) Zahlbr.	Crustose		6		2				Siliceous	Lecanoric, diploschistic
	D. gypsaceus (Ach.) Nyl.	Crustose						3		Sandstone	Lecanoric
	D. rampoddensis (Nyl.) Zahlbr.	Crustose			1	2	1	3		Siliceous	Lecanoric
	D. scruposus (Schreb.) Norman	Crustose						1		Siliceous	Lecanoric, diploschistic, orsellic
14	**Trapeliaceae**										
	Trapelia sp.	Crustose	2	1						Bauxite	Atranorin
15	**Trichotheliaceae**										
	Porina subinterestes (Nyl.) Müll. Arg.	Crustose				3				Siliceous	Atranorin
16	**Verrucariaceae**										
	Awasthiella indica Singh	Crustose				1				Sandstone	No chemicals
	Dermatocarpon vellereum Zschacke	Foliose	1							Siliceous	No chemicals
	Endocarpon nanum Singh & Upreti	Squamulose	3	4				1	2	Sandstone	No chemicals
	E. pusillum Hedwig	Squamulose						2		Sandstone	No chemicals
	E. pallidum Ach.	Squamulose		3						Sandstone	No chemicals
	E. rosettum Singh & Upreti	Squamulose						2		Sandstone	No chemicals
	E. subrosettum Singh & Upreti	Squamulose	2	7	1	2	2	2	1	Sandstone	No chemicals
	Staurothele fissa (Taylor) Zwack	Crustose		3	2	1		2		Siliceous	No chemicals
	Thelenella luridella (Nyl.) Mayrh.	Crustose	1							Bauxite	No chemicals
	Verrucaria coerulea (Ram.) DC. in Lam. & DC.	Crustose	3		1					Siliceous	No chemicals
	Lichen Imperfectii										
	Lepraria lobificans Nyl.	Leprose	1	6		2		1		Sandstone	Atranorin
	L. leidainii (Hue) R. Harris	Leprose						1		Siliceous	Triterpins

PLATE-1

Figs 1-5; Fig. 1. Bhimbetka Rock Shelter. Fig. 2. Rock cut statue at Dhar. Fig. 3. *Caloplaca awasthii* Joshi & Upreti. Fig. 4. *Caloplaca* sp. Fig 5. *Peltula euploca* (Ach.) Poelt ex Pisut.

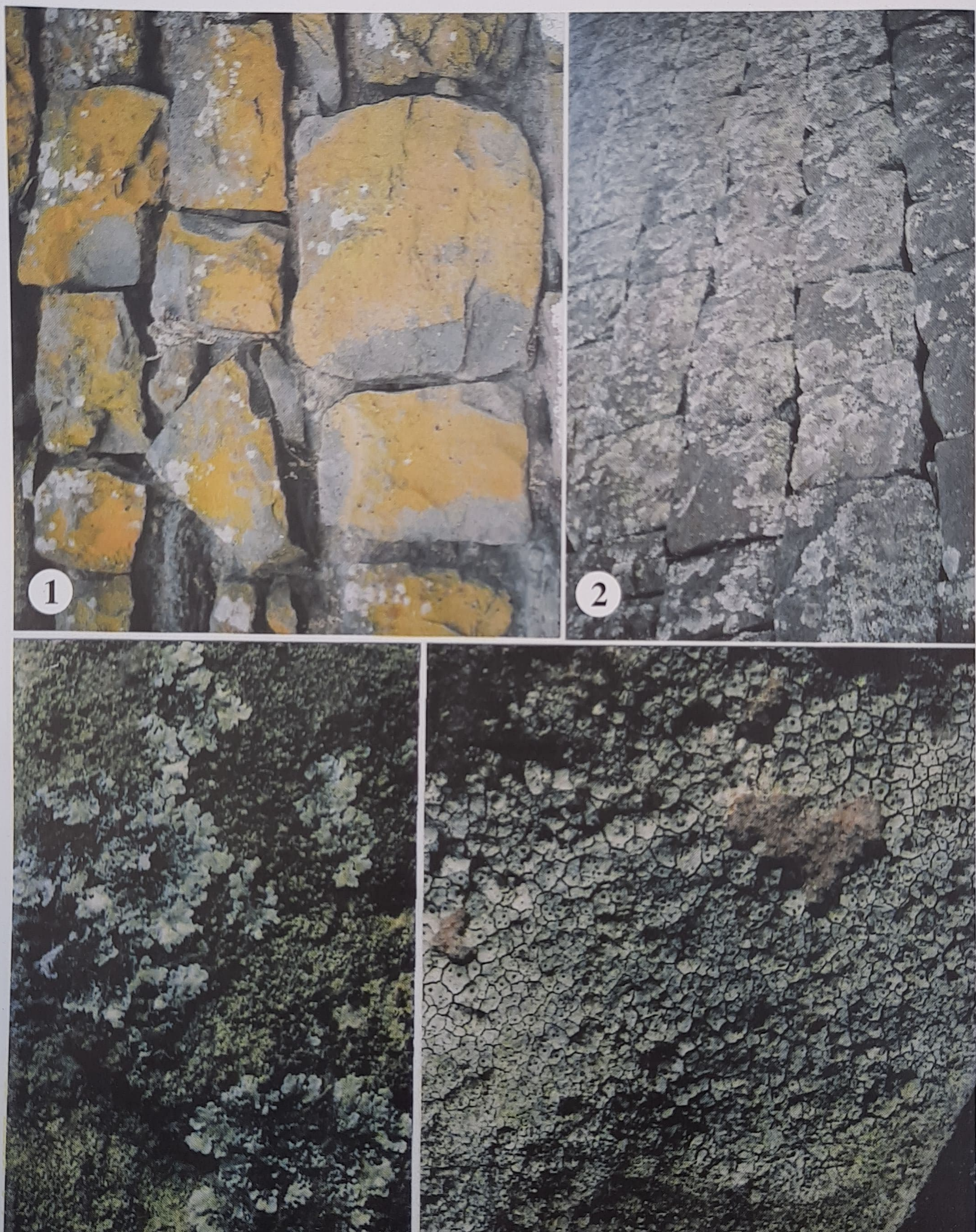

PLATE-2

Figs 1-4; Fig. 1. *Caloplaca cupulifera* (Vainio) Zahlbr. on wall at Alamgir gate, Dhar. Fig. 2. *Pyxine* and *Dirinaria* species on wall of Delhi gate, Dhar. Fig. 3. *Parmotrema praesorediosum* (Nyl.) Hale. Fig.4. *Diploschistes rampoddensis* (Nyl.) Zahlbr.

Table 3-Lichen growth forms in different districts.

Growth forms → District ↓	Crustose	Leprose	Squamulose	Foliose
Anoopur	9	1	4	14
Dhar	10	2	9	7
Dindori	6	0	3	5
Hosangabad	21	1	3	11
Jabalpur	5	1	4	4
Raisen	14	2	15	12
Tikamgarh	1	0	6	1

which causes biological weathering of rocks (Gehrmann *et al.*, 1988). According to Chen *et al.*, (2000), lichens contribute to mechanical weathering of monumental rock in four ways (a) by penetration of mycobiont hyphae in surface, (b) by expansion and contraction of lichen thalli with seasonal changes due to climatic factors, (c) by swelling action of organic salts produced by lichens and (d) by fracturing and incorporation of mineral fragments by lichen thalli.

Out of 95 species of lichnes recorded from the state monuments, 65 species belonging to 20 genera are closely addpressed to the substratum. They exhibit penetration of mycobiont or medullary hyphae in the substratum and also involve in oxalate crystal formation and metal complexing activity due to the presence of different lichen substances causing chelation of cations from rock minerals. The lichens not producing secondary substances (30 species) produce oxalate crystals causing biogeophysical weathering of the substrates.

Different lichen species actively involved in biodeterioration of carbonate, sandstone rocks and other lithic substrates. Lichens are capable of producing calcium oxalate on varieties of substrates. The warmer and drier sites are more conducive to the production of calcium oxalate dehydrates (Gehrmann *et al.*, 1988). The lichens with thick medullary zone (e.g. *Peltula*, and *Diploschistes* species) retain more moisture and also contain greater amounts of oxalic acid are thus responsible for more chemical decomposition of rocks.

Among the different lichens, species of *Caloplca, Buellia, Diploschistes, Lecanora* and *Lepraria* which form a thick crust over the substrate involve in biogeophysical and biogeochemical weathering are considered as the most effective biodeteriorant species of lichens. The species of *Dirinaria, Heterodermia, Phaeophyscia, Physcia, Pyxine, Parmotrema* and *Xanthoparmelia* being leafy in shape, attach to the substratum with few points on their lower side, are less effective biodetriorant than crustose ones.

Lichens commonly produce secondary chemicals, including various organic acids, which actively chelate substrate cations and thus modify the chemical and physical structure of mineral substrata (Jones & Wilson, 1980). Chen *et al.*, (2000) suggested that oxalic acid secreted by the lichen mycobionts is insoluble in water and react with the monumental rock substrates contaning Ca and Mg, to form the insoluble compounds of calcium and magnesium oxalates which accumulate on the surface of the substratum. The corrosion of rocks in the study area can not be ruled out as it has the drier and warmer climate coupled with luxuriant growth of oxalic acid and chelating substance producing lichens. The enumeration of lichens and their type of biodeterioration capacity data will be helpful in conducting future biomonitoring studies and to the conservators for adopting conservation practices for the monuments in Madhya Pradesh.

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