

Interesting observations on stone weathering of an Indian monument by lichens*

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Singh, Ajay & Dhawan, Shashi 1992. Interesting observations on stone weathering of an Indian monument by lichens. *Geophytology* 21 :119-123.

Qualitative assessment of damage caused by lichens to a 16th century stone monument, Yognarsimhaswami temple, Baggavalli, Kamataka is made. A species of *Leconora*, very commonly growing here contains large number of oxalate crystals, that have obviously been formed by reaction of oxalic acid produced by the lichen, on metallic cations of rock (substratum) minerals. Presence of lichen substances, such as atranorin in *Physcia tribacoides* and *Dirinaria consimilis*; and sekikaic acid in the latter species (in addition to atranorin) suggests, on account of their molecular structure, the metal complexing activity of these lichen products causing chelation of cations from rock minerals. Oxalate crystal formation and chelation involving metallic elements of minerals result in corrosion of the substratum, i.e., stone surface of walls or fine carvings of sculptures.

Key-words - Monuments, lichens, corrosion.

INTRODUCTION

Pedogenic activity of lichens is a well known phenomenon. Botanical text books term lichens as pioneers of the land plant succession. Such a reputation earned by these plants is undoubtedly due to their ability to colonize bare rock surface and to sustain continued existence there under harsh climatic conditions in the form of extreme and prolonged desiccation and wide, daily as well as seasonal temperature range; all this coupled with meagre nutritional availability. Other plant groups find these conditions hardly conducive to their survival. Lichens not only adhere firmly to the rock surface but also penetrate the rock and partly dissolve and digest its substance by their physical and vital activities. They are thus able to disintegrate rocks, and in collaboration with other biotic and abiotic factors convert them into soil. One hardly bothers if this phenomenon is occurring on natural rocks, but its spreading over the stone material used in man-made objects, such as monuments, statues, etc. draws attention of stone conservators for their preservation.

For a qualitative assessment of the damage caused to stone monuments by lichens in South India, a team of the project personnel visited a number of monuments in Karnataka state in Nov.-Dec., 1990. Different varieties of stones used in construction of South Indian temples is a vast study in itself. The three powerful Hindu dynasties, namely,

Chalukyas, Pallavas and Pandyas come to exist south of Vindhya in the latter part of the sixth century A.D. They made rich contributions to the south Indian architecture. Though Buddhists used stone material in construction of temples since earlier times, Hindus in south India refrained from doing so, as stone was associated with their funerary rites for a long time (Srinivasan, 1975). These dynasties, however, overcame this hesitation and adopted stone in architecture and sculpture related to gods and their abodes (temples). Srinivasan (1975) further states that the earlier used stones in construction of temples and fine carvings therein were fine-grained sandstone, marble-like limestone and much softer schist or soapstone or talc. They remained in use all over the peninsula till the advent of Vijayanagar Empire in the 14th century A.D., where hard granite rocks found favour as principal material for construction of buildings.

Our study is confined to a single stone monument of the 16th century A.D., i.e., the temple of Yognarsimhaswami (dedicated to Lord Vishnu), situated at Baggavalli, Tirikere, district Chikmangalur, Karnataka (Pl. 1, fig.1).

NATURE OF STONE USED IN CONSTRUCTION OF THE MONUMENTS

The rock material is a metamorphosed rock erroneously mentioned as granite in the abstract of this paper).

* Paper Presented at the Birbal Sahni Birth Centenary Palaeobotanical Conference, Lucknow, Novembr 20-22,1991.

Preliminary investigations reveal that the rock is feebly metamorphosed and highly altered. It seems to be composed of tremolite ($\text{Ca}_2\text{Mg}_5\text{Si}_8\text{O}_{22}(\text{OH})_2$) -actinolite ($\text{Ca}_2(\text{Mg,Fe})_5\text{Si}_8\text{O}_{22}(\text{OH})_2$). At places it shows feeble parallelism of grains, a few grains of quartz (SiO_2), plagioclase feldspar ($\text{Na, CaAl}_2\text{Si}_2\text{O}_8$), talc ($\text{Mg}_3(\text{Si}_4\text{O}_{10})(\text{OH})_2$), and some opaque minerals. At places some carbonate mineral, calcite/dolomite (Ca/MgCO_3) is also seen. On the basis of these investigations presumably the rock may be Tremolite-Actinolite schist.

SPECIES OF LICHENS COLLECTED FROM THE TEMPLE

While making collections it was our prime consideration to avoid even the least damage to the monument. It resulted in leaving behind a good number of lichen species, uncollected. Such species belonged to crustose forms, which, by and large, are difficult to identify in the field. Whatever material could be collected is listed below. The collected specimens have been numbered and are lodged at the lichen herbarium of N.R.L.C.

Caloplaca sp. (90.195A & 90.197A), *Candelaria indica* (Hue) Vainio (90.196C), *Diploschistes* sp. (90.195B & 90.197A), *Dirinaria consimilis* (Stirton) Awasthi (90.192A & 90.194), *Dirinaria* sp. (90.192B & 90.193), *Lecanora* sp.1 (90.196A), *Lecanora* sp.2 (90.195C & 90.196B), *Lecanora* sp.3 (90.198), and *Physcia tribacoides* Nyl. (90.191 & 90.196D).

NATURE OF DAMAGE CAUSED TO STONES

Hyphae of the fungal partner (mycobiont) of lichens excrete organic acids and a number of lichen substances. These excretory products react with the rock material of the substratum and bring about its slow chemical break down. Process of such weathering has been demonstrated at rock/lichen interface below the cover of lichen thallus, especially that of the crustose species (Hallbauer & Jahns, 1977). While investigating the lichen sponsored damage to Italian monuments, Ciarallo *et al.* (1985) noticed that in open air conditions lichen growth prevails over that of other micro-organisms and limestone is the most invaded substratum. More or less the same observations were made in the case in hand, except that the lichen growth on this temple was equalled to or even surpassed by that of the

higher plants.

The two probable types of chemical processes causing damage to the rock by the lichen growth are as follows :

In the first case, the oxalic acid produced by the thallus of *Lecanora* sp. 1 (90.196A), covering considerable part of sculptured surface (Pl. 1, fig.4) seems to have acted upon the metallic component of rock minerals, resulting in extracellular deposition of oxalate crystals within the lichen thallus (Text- fig.1).

The second type of damage to the stone material of this temple seems to be by chelation, or in other words, the metal complexing property of lichen acids. Such damage can only be assumed, based on circumstantial evidence. Out of several lichen species collected from the temple, *Physcia tribacoides* (Pl.1, figs 2,3) contains atranorin ($\text{C}_{19}\text{H}_{18}\text{O}_8$), and *Dirinaria consimilis* (Pl.1,fig.6) is characterized by presence of atranorin and sekikaic acid ($\text{C}_{22}\text{H}_{26}\text{O}_8$).

Chemically, both the substances are derived through acetate-polymalonate pathway of secondary lichen products. Atranorin, an accessory component of a large number of lichen species, confined mainly to the upper cortex of the thallus, is the sole substance present in *Physcia tribacoides*. However, it is generally accompanied with a principal component, i.e., some other lichen acid or acids deposited extracellularly in the medulla of the thallus, as is characterized by the presence of sekikaic acid in *Dirinaria consimilis*.

Atranorin is a para-depside, diaryl ester of β orcinol series, while sekikaic acid is a meta-depside, diaryl ester of orcinol series (Culberson, 1969).

Earlier, the lichen substances were considered to be insoluble in water, but Iskandar and Syers (1971) reported their solubility ranging between 7-75 mg/l of water. Syers and Iskandar (1973) considered their solubility in water due to presence of polar groups (e.g., in the present examples, -CHO in atranorin and -COOH in sekikaic acid) renders these substances soluble in water. Moreover, the presence of these donor groups in adjacent (ortho) positions (e.g., -OH, -CHO and -COOH) in the molecular structure of many lichen substances, including atranorin and sekikaic acid, provides them metal complexing property, that causes biological weathering of rocks (Gehrmann *et al.*, 1988).

As far as atranorin is concerned, Caneva and Salvadori (1988) experimentally demonstrated the chelating property by allowing it to react with water suspensions of some

PLATE I

1. The temple of Yognarsimhaswami, Baggavalli.
2. Patches of *Physcia tribacoides* growing along sheltered places of the temple platform.
3. Thallus of *Physcia tribacoides* (scale = 2.0 mm).

4. Part of sculptured panels at lower levels of temple wall, covered with *Lecanora* sp. 1
5. Enlargement of part of figure 4 (marked by arrow)
6. Thallus of *Dirinaria consimilis* (scale = 2.0 mm).

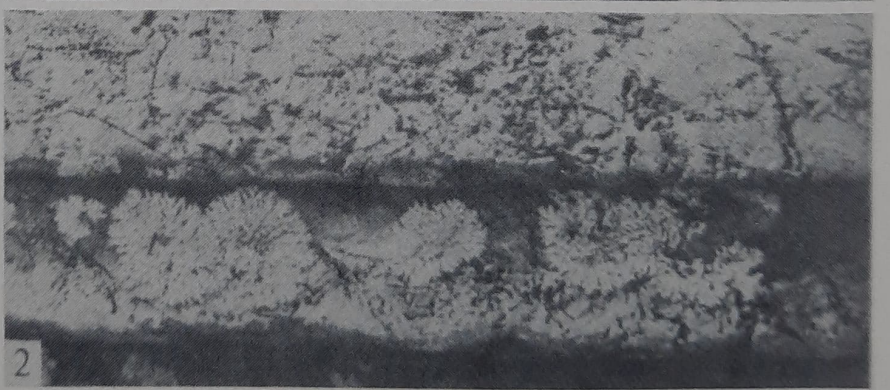
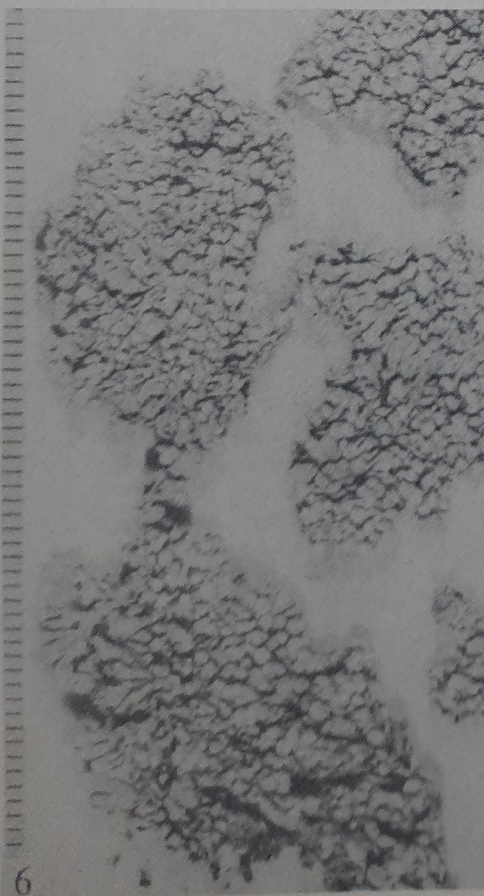
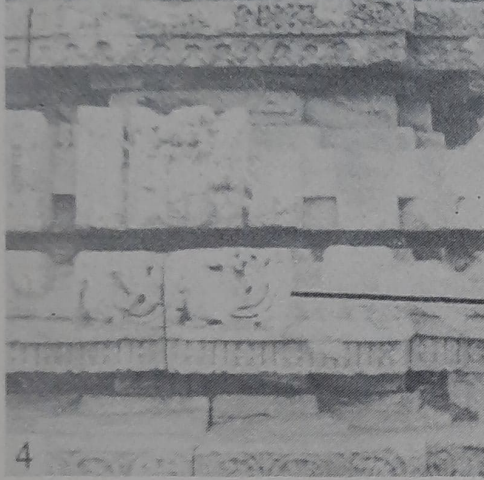
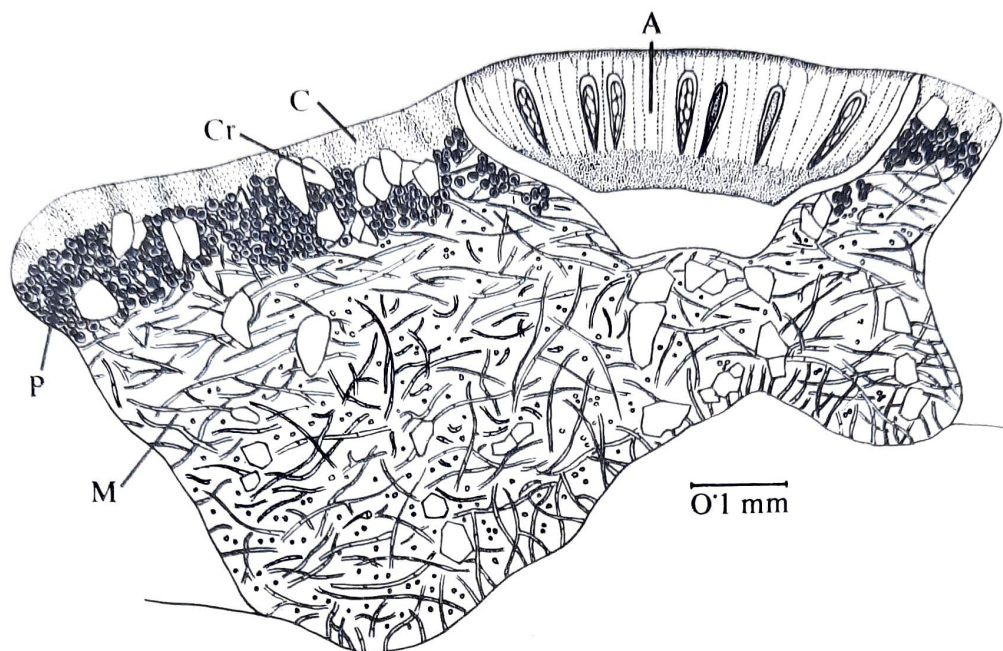


PLATE I



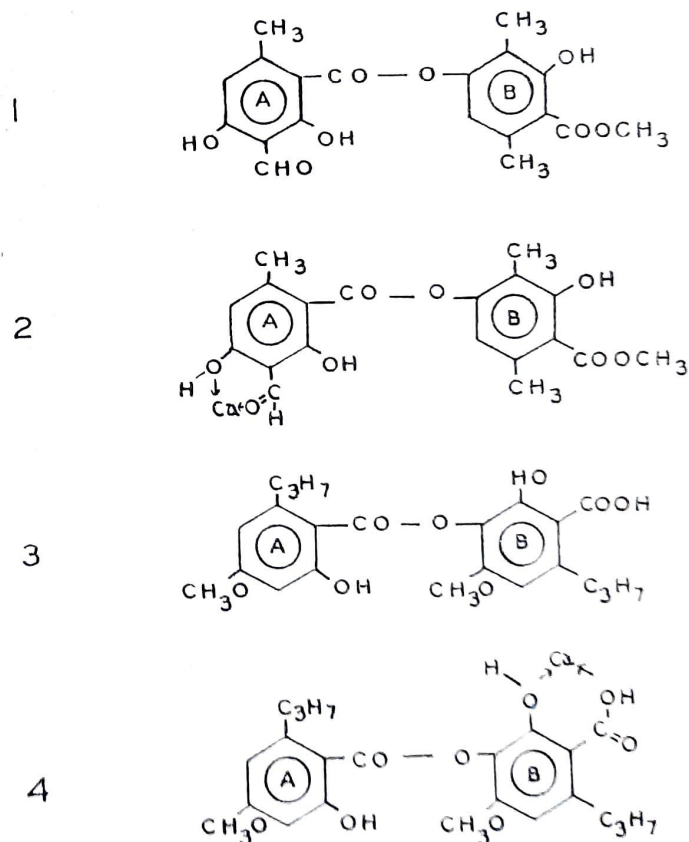
Text-figure 1. Vertical section of the thallus of *Lecanora* sp. 1. A-Apothecium
C-Corticiform layer, Cr-Crystals, P-Photobiont layer, M-Medulla.

finely powdered rocks, viz., biotite, granite and basalt, resulting in formation of coloured complexes. On a piece of rock overgrown with lichen collected from the field, Gehrman *et al.* (1988) clearly displayed by means of SEM photographs the disintegrating pattern on surfaces of marble and limestone caused by atranorin.

Theoretically, the chelation of calcium from rock mineral by atranorin can be explained as follows :

Calcium, for chelation from the rock mineral needs two pairs of electrons for its incorporation in the atranorin molecule. As visualized in the structural formula of this lichen substance one pair of electrons seems to be provided by oxygen of carbonyl of the aldehyde group (-CHO) in the ring A and the other from oxygen of one of the hydroxyl groups (-OH) in the vicinity within the molecule (Pl.1, figs 1,2 ; Text-fig.2).

In case of sekikaic acid the presence of carboxylic group (-COOH) is in all probability responsible for chelation of calcium from rock minerals. (Pl. 1, figs 3,4; Text-fig. 2). Based on the work of Schatz *et al.* (1954), Hale (1974) reproduced the theoretical mechanism for chelation of calcium by lecanoric acid, where the same group (-COOH) is supposed to bring about metal complexing process.



Text-figure 2. Molecular structure of atranorin. 2- Theoretical representation of metal complexing property of atranorin, 3-Molecular structure of sekikaic acid. 4- Theoretical representation of metal complexing property of sekikaic acid.

ACKNOWLEDGEMENTS

We express our sense of gratitude to the Director, Department of Archaeology and Museums, Government of Karnataka, Mysore for permitting one of us to undertake study of lichen growth on the monument and to collect lichens therefrom; to the Department of Science and Technology, New Delhi for funding the project; to the Director, National Research Laboratory for Conservation of Cultural Property, Lucknow for providing infrastructural facilities; to Dr. D. D. Awasthi, Department of Geology, Lucknow University and Shri Manoj Rastogi for help in investigations of the rock material; to Dr. Gopal Mishra, National Botanical Research Institute for help in dealing the chemical aspect of lichen substances; and to Shri Anil Risal Singh and Shri S.S. Rana for help in printing of photographs and preparation of some line diagrams respectively; and to Shri Shantanu Chatterjee and Shri Surendra Singh for their help in various ways in preparation of this paper.

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