Mineralogical studies on calcareous algae

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Calcium carbonate deposition in 17 algal species was studied using X-ray diffraction technique. Argonite was the predominant mineral deposit in chlorophytic genera: *Halimeda, Udotea, Acetabularia,* Phaeophytic genus: *Padina* and Rhodophycean genera: *Actinotrichia* and *Galaxaura.* In Corallinaceous forms like *Amphiroa, Jania* and *Cheilosporum* high magnesium calcite was the predominant mineral. Halite, illite, quartz and feldspar were the major contaminants from surrounding media.

It is well known that almost all algal phyla have some genera which can accumulate various inorganic substance within or around the cell. However, the predominant mineral deposit of algae is calcium carbonate in the form of calcite and aragonite[1]. The density of forms and the organization among various calcium deposits were earlier studied by X-ray diffraction and chemical analysis[2,3]. Mineral components of udoteacean members were also studied[4,5]. Argonite deposits in nemaliales and *Padina* were reported by various workers[4,6,7]. Calcite deposition in the calcified members of cryptonemiales was also extensively studied[1,6,8].

Calcified algae occurring along the Indian coast have so far remained uninvestigated for their mineralogical aspects. To fill this gap an attempt was made to study the calcium deposits of 17 algae belonging to three algal groups.

Species of *Halimeda, Udotea, Acetabulaira* (Chlorophyceae) (from Okha–Gujarat and Andaman respectively), *Padina* (Phaeophyceae) (Anjuna–Goa), *Actinotrichia, Galaxaura, Amphiroa, Jania* and *Cheilosporum* (Rhodophyceae) (From Lakshadweep) were analysed for determining the nature of calcium using X-ray diffractometer (No. 1840) using nickel-filtered CuK_α radiations. Samples were scanned from 25° to 35° 2θ (the instrumental conditions were 40 kV and 20 mÅ).

Minerals were identified using JCPDF (Joint Commission of Powder Diffraction File) cards (X-ray diffractions identified at 26.2, 27.2, 33.12° 2θ are aragonite, 26.4° 2θ are illite, 26 6° 2θ as quartz, 28.3° 2θ feldspar and 20.93° 2θ high magnesium calcite and 31.8° 2θ as halite).

Diffraction patterns produced by all chlorophycean forms (Figure 1 *a, b, c*) *Padina* (Figure 1 *d*) and by members of nemaliales were attributable to aragonite, while calcite was the predominant deposit in the members of family Corallinaceae (Rhodophyceae—Cryptonemiales) (Figure 1 *e, f, g*). Other minerals like quartz, halite, illite and feldspar were also found to be present in almost all forms. Identified minerals of the species studied with

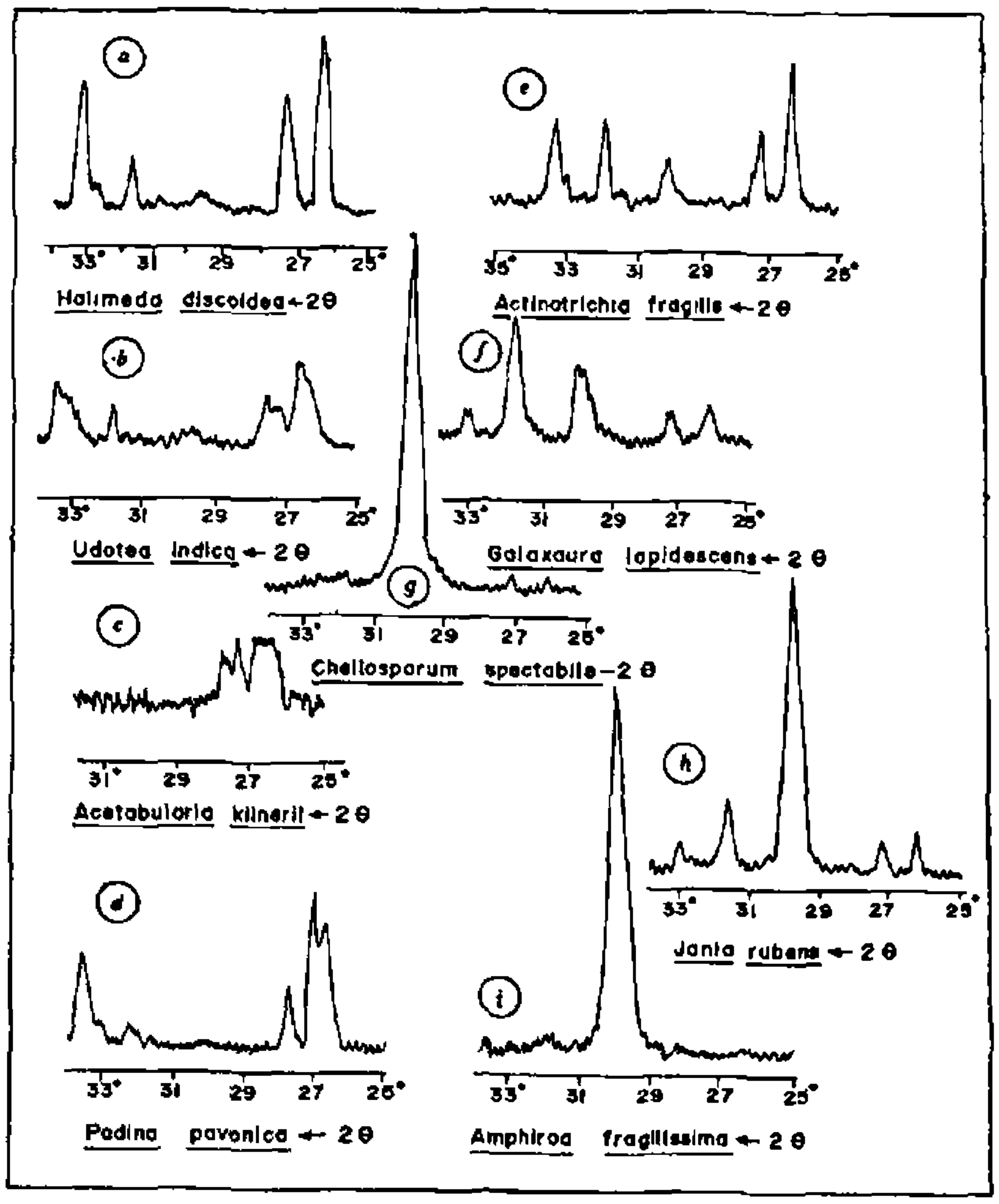

Figure 1. Mineral deposits in some calcified algae.

their decreasing abundance are listed in Table 1. Diffraction patterns produced by these algae (representative of each genus) are shown in Figure 1.

All *Halimeda* species i.e. *Halimeda gracilis, H. incrassata, H. opuntia* and *Udotea indica* (chlorophyta-udoteaceae) produced diffraction patterns which were essentially attributable to aragonite. McConnell and Collinvaux (1967) studied aragonitic deposition in *H. monile* and *H. tuna*. Aragonite needles in other udoteacean genera like *Penicillus, Rhipidocephalus* and *Tydemania* were reported by Lowenstam[4] and McConnell and Hillis[4]. It can be concluded that aragonite is the predominant mineral deposit in udoteacean forms.

Mineralization in *Acetabularia kilneri* (Chlorophyta—Dasycladales) was also found to be aragonitic which is in agreement with Vinogradov[1], Levy and Strauss[6] and Borowitzka[7] who studied the aragonitic needles in Dasycladales.

Padina pavonica (Phaeophyta—Dictyotaceae) was observed to deposit aragonite confirming the observations by Levy and Strauss[6].

Galaxaure species i.e. *G. lapidescens, G. lenta, G. marginata, G. oblongata* and *Actinotrichia fragilis* (Rhodophyta—Nemaliales) showed aragonite as the predominant deposit which is in agreement with Lowenstam, Borowitzka and co-workers[4,7].

Table 1. Minerals deposited in the species studied

Species studied	Identified minerals in decreasing abundance
Halimeda discoidea	Aragonite, halite
H. gracilis	Aragonite, illite, feldspar
H. incrassata	Aragonite, feldspar, halite
H. opuntia	Aragonite, quartz
Udotea indica	Aragonite, halite
Acetabularia kilneri	Aragonite, quartz
Padina pavonica	Aragonite-quartz, illite, feldspar
Actinotrichia fragilis	Aragonite, high magnesium calcite, halite
Galaxaura lapidescens	Aragonite, high magnesium calcite, halite
G. lenta	Aragonite, feldspar, high magnesium calcite, halite
G. marginata	Aragonite, feldspar, high magnesium calcite, halite
G. oblongata	Aragonite, feldspar, halite
Amphiroa anastomosans	High magnesium calcite, quartz
A. foliacea	High magnesium calcite
A. fragilissima	– do –
Cheilosporum spectabile	– do –

High magnesium calcite was observed to be the predominant mineral deposit in all members of family Corallinaceae i.e. species *Amphiroa*, *Jania*, *Cheilosporum* and *Arthrocardia* confirming Vinogradov's[1] observation. Borowitzka[8] and Johansen[9] reported that high ambient temperature of the surrounding medium facilitates the incorporation of magnesium in the cell wall. India being a tropical region, water temperature is relatively higher and this probably accounts for the deposition of high magnesium calcite in these forms.

Other minerals like quartz, halite, illite and feldspar were also present in almost all forms which are possibly related to the contamination from detritus, seawater or organisms growing on or in the specimen.

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Chemoheterotrophy in the mangrove environment

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The unique characteristics of the mangrove ecosystem of the tropics are discussed. This ecosystem is endowed with a diversity of habitats within it and is chemoheterotrophic in nature. The production of photosynthetic prokaryotes under chemoheterotrophic conditions is discussed. Nitrogen fixation by planktonic cyanobacteria to augment nitrogen budget of the ecosystem has been worked out. The heterotrophic growth of photoautotrophic prokaryotes as a mechanism of natural evolution to survive in hostile coastal anaerobic and anoxic conditions is emphasized.

THE mangrove or tidal forests are one of the major ecosystems of the biosphere. According to McGill[1], 60–75% of the tropical coasts are covered by mangroves. The unique mangrove forest ecosystem comprises three dominant constituents: forest, water and land. The banks of intricately woven canals, meandering channels and gullies of the mangrove ecosystems are bordered by species belonging to *Avicennia*, *Rhizophora*, *Bruguiera*, *Ceriops* and *Excoecaria*. During low tide the muddy shores get exposed in mangrove ecosystems. The waterways consist of varying degrees of admixed composition of freshwater-brackish water-sea water in its various regions. The muddy shores, mudflats, stilt roots of vegetation like *Rhizophora* within the mangrove ecosystems provide many an ideal habitat and ecological niche for many organisms like photosynthetic prokaryotes, lichens, molluscs, etc. The mangrove ecosystem also induces the production of H_2S in many localized pockets because of the presence of sulphur-reducing bacteria. They find it an ideal environment due to putrefaction of organic matter under the prevailing anoxic conditions of its 'reducing environment' in certain areas.

In short, the mangrove ecosystem with its diversity of habitats and milieu harbours equally diversified microbial flora and biota. The nutritional requirement of microflora also differs widely ranging from photoautotrophic conditions in photosynthetic bacteria and cyanobacteria to chemoheterotrophic conditions in some bacteria.

In this paper we discuss their microbial ecology based on our studies at Pichavaram mangroves (Lat. 11° 29′ N; Long. 79° 46′ E) in Parangipettai, the southeast coast of India. Samples were collected fortnightly at two stations in the Pichavaram mangroves from January to December 1989 (Figure 1). The standing crop of epiphytic and benthic cyanobacteria was estimated by scrapping