SOME OBSERVATIONS ON THE CALCIFIED MARINE ALGAE ALONG THE INDIAN COAST

THESIS SUBMITTED TO

THE GOA UNIVERSITY

FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

IN

MARINE SCIENCE

BY

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DECEMBER, 1989

CERTIFICATE

Miss Vijaya Dattaram Ambiye has been working under my guidance since 1986. The Ph. D. thesis entitled "Some observations on the Calcified Marine Algae along the Indian Coast" submitted by her contains the results of her original investigations on the subject. This is to certify that this thesis has not been the basis for the award of any other research degree or diploma of any University.

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TO MY PARENTS

ACKNOWLEDGEMENTS

I wish to express my sincere gratitude to Dr. A. G Untawale, Scientist, N. I O for his untiring guidance and encouragement throughout the stages of this work.

My sincere thanks to Dr. B. N. Desai, Director, N. I O and Dr. A. H. Parulekar, Head, Biological Oceanography Division for facilities provided and encouragement.

I also record my sincere thanks to Dr. B. B. Chaugule, Botany Department, Poona University for providing many algal samples from remote localities. I also thank him and Dr. V. Krishnamurthy, C.A.S Botany, Madras University for their help in the identification of seaweeds.

Thanks are also due to Sridhar Iyer, V. P. C. Rao, Parthiban, Shekhar Rivonkar, N.I.O. for their valuable help in the study of mineral deposits. I also take this opportunity to thank Mrs. Prita Ramani for her help in animal identification. I also thank Dr. Corneil Rodrigues, Marine Science Department, Goa University, for his help in numerical analysis.

I thank all my colleagues who helped me a lot for carrying out this work. Specific mention should be made of Dr. V. K. Dhargalkar for the constructive suggestions, Dr. T. G Jagtap for allowing me to refer to his subtidal algal collection. Thanks are also due to Miss Medha Joshi and Miss Shubhada Acharya for helping me variously in the preparation of the thesis.

I will be failing in my duties if I won't acknowledge the clarity and hardship shown by Ms. Philomena Estrocio while typing out this thesis. Help rendered by the Photography and Drawing Sections is gratefully acknowledged.

I also thank Dr. David Garbary, who guided me for S.E.M. work. I also thank him and Dr. Y. M. Chamberlain, Dr. Jerry Bakus, Dr. H. W Johansen and Dr. T. Masaki for sending me photocopies of valuable reprints.

I gratefully acknowledge the financial help received from INDO - U.S project (Bioactive Compounds from Marine Organisms).

I humbly register my thanks to my parents Mr. D. A. Ambiye and (Late) Mrs. Laxmi Ambiye, who have been the perennial source of encouragement. I thank them for all they have done to me and to whom I dedicate this work.

Dona Paula, Goa.
Dated 18 th December, 1989.

(Vijaya Ambiye)

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ABBREVIATIONS USED IN THE THESIS

AC - Apical cell
AF - Assimilatory filament
AND - Andamans
ANG - Angria
AP - Apical papillae
BDP - Bassas de-Pedro
CB - Carpogonial branch
CBI - Carpogonial branch initial
CH - Chromatophores
COC - Cover cells
CO - Cortex
CRD - Cora-Divh
CS - Carpospores
CST - Cysts
EP - Epidermis
FC - Fusion cell
GEN - Geniculum
GF - Gonimoblast filament
GI - Gonimoblast initial
GUJ - Gujarat
H - Hair
I.Co - Inferior corona
IND - Indusium
KAR - Karnataka
KER - Kerala
LAF - Long assimilatory filament
LAK - Lakshadweep
LC - Long cells
MAH - Maharashtra
ME - Medulla
MF - Medullary filament
OST - Ostiole
PAR - Paraphyses
PB - Primary branch
PC - Pit connection
PRI - Pericarp initials
RH - Rhizoids
SAF - Short assimilatory filament
SB - Secondary branch
SC - Short cells
S.Co - Superior corona
SF - Sterile filament
SP - Spermatangium
SPC - Secondary pit connection
SST - Sessotris
STC - Stalk cell
TAM - Tamil Nadu
TMC - Tetraspore mother cell
Tr - Trichogyne
Trc - Trichocytes
⊕ Sp - Tetraspores
⊕ Spg - Tetrasporangium

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um - µm (micrometer)

CHAPTER 1

GENERAL INTRODUCTION

Oceans support marine plants which include the algae, fungi, lichens, angiosperms, etc. Algae is the most dominant group amongst this marine vegetation. In marine ecosystems, algae are the important components of benthic plants, reefs, as well as of estuarine ecosystems and are described as 'seaweed ecosystems' (Unesco, 1980). Among the marine plants, seaweed ecosystems have been recognized to be important in relation to other organisms of the sea (Fuse, 1962). Their roles in nutrient cycling and fixing energy in the coastal regions are also very important (Littler & Arnold, 1982; Norton, 1985). Seaweeds have contributed to human life especially as utility in natural ecosystems, food for man, livestock and as industrial materials. Seaweeds have been utilized as food staples and delicacies for thousands of years. Considering their significant potentiality, it is being said that, seaweeds can become our food and energy resources of the 21st century (Leeper, 1976). Marine algae have been recently investigated for the production of methane gas (Hanisak, 1981), paper (Kiran et. al., 1980), bioactive compounds used in pharmacy (Hoppe et. al., 1979), dyes (Novak & Rasmussen, 1981) and in human diseases (Stein and Borden, 1984). Thus, man has turned to the oceans as a possible source of energy as also for other needs.

Trainor (1978), has defined algae as, "photosynthetic, non vascular plants containing chlorophyll 'a' and having simple reproductive structures". Four major groups of macroscopic algae make up most of the benthic flora, namely, blue-green algae (Cyanophyta) green algae (Chlorophyta), brown algae (Phaeophyta) and red algae (Rhodophyta). All the groups contain a wide variety of forms ranging in structural complexity from simple unicellular to very complex multicellular types. In due course, owing to evolution, a few members of these groups developed the ability to secrete lime and are commonly known as 'CALCIFIED ALGAE'. The carbonate skeleton functions as a supportive and protective material in many algae, while in others, it is extraneous to the organisms' vital activity (Wray, 1977).

I) <u>TAXONOMIC POSITION</u>

Calcified algae are scattered in all the major divisions i.e. Cyanophyta, Chlorophyta, Phaeophyta and Rhodophyta. As far as macroscopic calcified algae are concerned, mention should be made of udoteacean, dasycladacean (Chlorophyta) forms. '<u>Padina</u>' the only calcified brown alga belongs to the family Dictyotaceae (Phaeophyta - Dictyotales). Amongst Rhodophyta a few members of the order Nemalionales and Cryptonemiales are calcified. (Nemalionales-Chaetangiaceae, and Helminthocladiaceae, Cryptonemiales - Corallinaceae and Peyssoneliaceae) (Fritsch, 1935, 1945; Bold and Wynne, 1978). Recently Johansen (1969a) has recognized six subfamilies viz. Melobesioideae, Lithophylloideae, Mastophoroideae, Schmitzielloideae, Amphiroideae, Corallinoideae Metagoniolithoideae. Furthermore, it has been suggested that Corallinoidean genera fall into two groups i.e. <u>Corallina</u> & <u>Jania</u> group, (Johansen, 1970). Johansen and Silva (1978) suggested that two tribes, 'Janiae' and 'Corallineae' should be recognized in the sub family Corallinoideae. Table 1 represents the systematic position, habitats and deposits of calcified algae.

Table 1 - The nature of algal calcium carbonate deposits and their distribution among the algal groups. (Adopted and modified from Borowitzka, *et. al.*, 1974, 1982).

Algal groups			Habitat	Crystal type*
Phylum	:	*Cyanophyta*	Freshwater & marine	Calcite (usually)
Phylum	:	*Chrysophyta*		
Family	:	Coccolithophoridaceae	marine	Calcite (usually)
Phylum	:	*Chlorophyta*		
Order	:	Dasycladales	marine	Aragonite
Order	:	Caulerpales	marine	Aragonite
Phylum	:	*Charophyta*		
Order	:	Charales	Fresh water	Calcite
Phylum	:	*Phaeophyta*		
Order	:	Dictyotales (only *Padina*)	marine	Aragonite
Phylum	:	*Rhodophyta*		
Order	:	Nemalionales	marine	Aragonite
Order	:	Cryptonemiales	marine	Calcite

* "Calcite" is the hexagonal-rhombohedral form of $CaCO_3$

"Aragonite" is the orthorhombic form

II. GENERAL STRUCTURE AND REPRODUCTION IN CALCIFIED ALGAE

Members of family "Udoteaceae" (Chlorophyta) exhibit an unique organization, in that they are composed of richly branched siphons in the more specialised types to form a compact parenchymatous body. The axial siphon exhibits an apical growth and branches dichotomously. Sometimes laterals are produced abundantly from this axial siphon. In Udotea, dichotomously branched siphons unite in the lower region to form a loose cylindrical stalk, while at the top they diverge to form brush like tufts, commonly spread out to form a small flat fan (Fritsch, 1935). In Halimeda, complex organization of an internode is the result of ramification and interweaving of coenocytic filaments. Inner multiaxial core of lengthwise extending medullary filaments branch trichotomously. Utricles develop from the lateral branches of the central filaments (Hillis, 1980).

Dasycladacean members (Chlorophyta) are characterised by their whorled branching and by the development of specially differentiated reproductive organs. In Neomeris, a club shaped main axis bears whorls of laterals, which are branched to the third degree. Deciduous hair are developed by the ultimate branches, these whorls become compact and dilated. Swollen ends of the secondary branches form a faceted surface. Gametangia are formed throughout and appear terminal on the primary branches. (Fritsch, 1935). In Acetabularia, main axis bears several whorls of repeated branches, terminating above in a disk and rhizoids below. Cells of the disks bear projections called as 'coronae'. Reproduction takes place by means of cysts, which are produced in the rays (Bold & Wynne, 1978; Taylor, 1950).

Padina, the only calcified Phaeophycean form has an inrolled margin with a marginal row of apical cells which split and form proliferous rounded or spathulate blades. Thallus gets attached by an irregular holdfast (Taylor, 1950).

In the filamentous thalli like Liagora (Nemalionales-Rhodophyta), the central axis is structurally composed of a strand of medullary filaments. The lateral fascicles of the branches form the cortex. Carpogonial branches originate from the inner part of the lateral fascicles, while antheridia form subglobular tufts or flattened clusters, near the outer ends of the cortical filaments. As far as Galaxaura and Actinotrichia are concerned, central axis is made up of colourless filaments and a cortex of branches with conspicuous chromatophores. Carpogonial branches on the inner portion of the cortex and are generally short (about 3 celled). Fertilized carpogonium gives rise to gonimoblast and the end cells of these form the carpospores. Antheridia are scattered over the surface or occur in sunken conceptacles. Tetrasporangia if present, are superficial in position (Kylin, 1956).

In the family Corallinaceae, filaments are united laterally and except in "genicula", these tissues are heavily impregnated with calcite. "Epithallium" which is made up of short cells covers the calcified part of the thallus. Cortex is made up of short celled photosynthetic tissues. Medulla consists of long celled non-photosynthetic tissue which constitutes the core of the branches. "Tetrasporangia" are in sori and lie embedded within the thallus. "Carpogonia" and "Auxiliary cells" are in groups and enclosed in the conceptacles. They are borne together on erect filaments arising from the base of conceptacles. "Gonimoblasts" are abundant and arise from the margin of long cells formed after fertilization followed by the fusion of the auxiliary cell. The antheridial conceptacles open at the top or on the side, by developing a pore (Johansen, 1974).

III. DISTRIBUTION OF CALCIFIED ALGAE

Calcified algae are ubiquitous in nature (Fritsch 1935, 1945). Dawson (1966) has enlisted 50 living genera and 649 species of calcified algae. Out of these 50 genera, 26 belong to the tropical region while 24 are found in temperate environment.

Distribution of algae represents their adaptations to the considerable number of factors which are generalised below :

1. Temperature : A large number of calcified algae occur only in the tropical waters while some others are found in temperate waters (Dawson, 1966). Luxuriant growth of crustose forms is observed in the tropics (Johnson, 1961). Similarly, members of Codiales, Dasycladales favour warm waters (Fritsch, 1935, 1945). Articulated corallines have ability to withstand considerable temperature ranges (Johansen, 1974).

2. Salinity : Amongst articulated coralline algae, *Corallina officinalis* has been reported to tolerate appreciable freshening of water (Johnson, 1961). While Dasycladales and Codiales are

strictly marine (Fritsch, 1945). King & Schramm (1982) have reported that low salinity shows adverse effects on calcification

3. <u>Depth</u> : Articulated Corallines are found to be abundant in the areas having high tidal amplitudes (Johansen, 1974). Taylor (1950) has reported maximum growth of <u>Halimeda</u> spp. in the lagoons.

4. <u>Light</u> : In clean oceanic waters green and coralline algae grow as deep as 175 meters where the irradiance is about 0.05% of that of the surface (Lüning, 1981a). Pia (1920) concluded that Dasyclads avoid direct sunlight and hence are mostly found growing at the underside of rocks.

5. <u>Wave action</u> : Algae have various means for reducing the drag caused by wave action. The ability to bend freely is important in reducing drags. Thus all the articulated corallines are flexible owing to of their noncalcified geniculae (Lobban <u>et. al</u>., 1985). Thalli of <u>Penicillus</u> spp growing in deeper waters are rounded where the wave action is insignificant. However, in shallow areas, where waves come from one predominant direction, the stipe and bushy capitulum are flattened and oriented with the flat side, which is perpendicular to the direction of waves. This feature is observed in <u>Udotea</u> sp. (Friedman & Roth, 1972).

6. <u>Substratum</u> : Articulated corallines are abundant in the rocky region (Johanson, 1974). <u>H</u>. <u>opuntia</u> generally prefers sandy substratum as the holdfast is of creeping type, as also by <u>H</u>. <u>simulans</u> and <u>H</u>. <u>macroloba</u> because of the burrowing nature of their holdfast (Hillis 1980). Pia (1920) and Taylor (1950) have

stated that Dasyclads grow on the underside of coralline rocks.

7. Grazing : According to Lembi and Waaland (1988), grazing is the most important factor determining the distribution of algae. Algae possess characteristics that minimize the impact of grazing by producing calcareous material, toxins or by having short life histories and alternation of generations, etc.

IV. CALCIFICATION

Deposition of $CaCO_3$ around or within the cell wall can be the general definition of calcification. Way of lime deposition, amount of calcification may vary from group to group even from genus to genus. Among green forms calcification involves most of the tissue, it starts at the outer portions and works inward (Johnson, 1961).

Pioneering studies of Goreau (1963) have shown that light stimulates calcification in most calcareous algae. Pentecost (1978) showed that, calcification in coralline alga '*Corallina officinalis*' is directly related to the rate of photosynthesis. Smith & Roth (1979) showed that calcification rate is related to the inorganic carbon concentration in the medium. Lewin (1962), Borowitzka (1982), Littler (1976), Pentecost (1978) are the valuable contributions to review the structural aspects of calcification. According to Borowitzka (1982), the mechanism of calcification may be biochemical or metabolically controlled or it may be purely physical mechanism resulting from a combination of anatomical and physiological properties of algae.

Borowitzka (1982) has suggested that, carbonate equilibria in solution, the physical chemistry and kinetics of Calcium carbonate are important in crystal-nucleation and crystallization. Also important in the process of calcification are the organic substances such as promotors, inhibitors or regulators of crystallization.

It is known that calcification results from pH changes caused by CO_2 uptake in photosynthesis. But this is also valid with other noncalcareous forms, but they do not get calcified. The reason for this is, non calcareous algae release compounds which inhibit $CaCO_3$ nucleation and precipitation. High phosphate concentration in the surrounding medium is also known to inhibit calcification process (Simkiss, 1964; Brown et. al., 1977). Exudation of polyphenols, among Phaeophycean members hampers calcite precipitation (Reynold, 1978). Absence of these polyphenols in *Padina* encourages calcification in this genus (Sieburth and Jensen, 1969). Algae excrete a wide range of substances including carbohydrates (Seiburth, 1969), lipids (Hellebust, 1965) organic acids (Hellebust, 1974), organic phosphates (Johannes, 1964) and any one of these could act as inhibitors of $CaCO_3$ nucleation and precipitation.

V. MINERALIZATION

The summary by Lewin (1962), indicates that relatively few investigations on algal calcification have been reported. The predominant mineral deposit of algae is Calcium carbonate in the form of "Calcite" and "Aragonite" (Vinogradov, 1953; Lewin, 1962). Some algae are known to deposit small amounts of

Magnesium carbonate (magnesite), Strontium carbonate (strontite) and Magnesium hydroxide (brucite) (Borowitzka _et_. _al_., 1974). Diversity of forms and organization among the various calcium carbonate deposits of many genera have been studied using X-Ray Diffraction and the chemical analysis, by Bass-Becking and Galliher (1931), McConnell and Colinvaux (1967), Perkins _et_. _al_. (1972), etc. The nature of algal calcium carbonate deposits and their distribution among the algal groups is shown in Table 1.

Marszalek (1971), proved the usefulness of Scanning Electron Microscopy in the study of aragonite deposits of the Caulerpales. Borowitzka _et_. _al_., (1974) studied broadly the calcium carbonate deposits of major phyla. Red algae were initially studied with the help of SEM by Bailey and Bilasputra (1970) while studying _Corallina_ and _Calliarthon_. The introduction of SEM in the taxonomy of Coralline algae was first proposed by Garbary (1978) and subsequent studies (Garbary and Scagel, 1979; Garbary and Veltkamp, 1980; Garbary _et_. _al_., 1981) have shown that this tool offers a great potential in the field of taxonomy.

VI. ECONOMIC IMPORTANCE OF CALCIFIED ALGAE

1) _Calcified algae and fossils_ : Minerology and extent of calcification are important factors in the process of fossilization. Calcified algae comprise the oldest fossils known, and their remains occur in the rocks of all the ages from Precambrian to recent times (Wray, 1977).

2. _Calcified algae and lime stones_ : Johnson (1961) has divided algal limestones depending on their structure and properties

into 'Porcelainaceous', 'Reef limestones', 'Stromatolitic limestones', 'Algal felts' as well as 'sponges and leached or partially leached limestones'. These limestone deposits have been associated with petroleum reserves, this relationship is drawing the attention of many geologists, palentologists and botanists.

3. Calcified algae and sediment production : Calcified algae are actively involved in the reef formation. Carbonate sediments accumulate mainly in shallow tropical seas since the greatest diversity of calcified organisms occur in these areas. High magnesium calcite of articulated and crustose corallines provide essential binding and cementing structures. Halimeda is the major source of calcareous sand as well as larger particles. It is also frequently abundant in the lagoons constituting 50% of the volume of bottom sediments (Ginsburg, 1976). Quantitative estimate of lime-mud production by the fragile codiacean alga Penicillus was estimated by Stockman et. al. (1967) and Udotea, Rhipocephalus by Neumman & Land (1975). The brown alga Padina and red alga Galaxaura although lightly calcified are noteworthy sediment sources (Land, 1970).

4. Calcified algae and bioactive compounds : Most of the calcified algae are known for the production of chemical deterents. 'Udoteal' is the lipoid in Udotea flabellum which deters herbivorous fish (Paul et. al., 1982). Many species of Halimeda are ichthyotoxic (Paul and Hay, 1986). These toxins are known to produce 'diacetoxybutadine' containing terpenes which

deters grazing fish (Targett et. al., 1986). The herbivorous fish Sparisoma radians avoided the milky exudate released from the injured tips of green alga Halimeda incrassata, this is reported by Targett et. al., (1986). Articulate coralline alga Amphiroa fragilissima contains biogenic amine (Solimabi et. al., 1987) which shows hypotensive activity.

VII. SUMMARY OF THE PREVIOUS WORK CARRIED OUT IN INDIA

India with a vast coastline harbours 624 marine algae (Untawale et. al., 1983). Marine algal flora of Indian continent in the 18th and 19th century is studied by European naturalists viz. C. Agardh (1823, 1824); J. Agardh (1848); Boergesen (1930, 1946). They studied the flora of South India whereas Kuntze (1881), Barton (1903a) studied the marine algae of Andaman & Nicobar Island groups and of Lakshadweep and Minicoy atolls respectively. (C.f. Srinivasan 1965 a,b, 1966).

Recently i.e. in the 20th century, Biswas (1949a, 1949b), Dixit (1940), Srinivasan (1960, 1965a, 1965b, 1966), Krishnamurthy & Joshi (1970), Umamaheswara Rao (1969), Untawale et. al. (1983) studied the marine algal flora of various parts of the country. (C.f. Krishnamurthy V., 1985). Boergesen (1930, 1937) ; Balkrishnan (1946, 1955), Chacko (1955), Desikachary (1957, 1966), Hillis (1959), Umamaheswara Rao (1969), Thivy (1959), Misra (1960, 1966), Varma (1960) contributed towards the ecology, distribution and taxonomy of some calcified forms but these reports provide very scanty information. However exception is of Ganesan (1965, 1967) who gave the taxonomic account of Amphiroa, Arthrocardia and Jania spp. But still there is lack of continuity in the studies of other articulated corallines. Jayagopal (1984) studied the crustose corallines of Tamil Nadu, whereas Sundararajan (1984) has described the species of Galaxaura, Liagora along with other nemaliales from the taxonomic point of view.

VIII. OBJECTIVES OF PRESENT STUDY

Literature analysis shows that, very little information is available about Indian calcified forms. Details of their habitat, distribution, ecology, mineral deposits are not yet known. With the exception of a few, these forms are also not studied for their vegetative and reproductive details.

In view of these gaps and also taking into consideration the importance of calcareous algae, an attempt is made here to study them, keeping in mind the following objectives.

1. To study the calcified flora along the coastline, oceanic islands and of deep water areas.

2. To study the floral affinities between various stations of diverse habitats.

3. To determine the possible factors affecting the distribution of calcified algae.

4. To report any new algal genera or species to the Indian coasts.

5. To study calcified algae for their vegetative and reproductive morphologies.

6. To study the nature of minerals deposited.

7. To observe the surface morphological features.

8. To assess the percentage of Ca and Mg in the deposits.

9. To study the effect of hydrological parameters like dissolved oxygen, salinity, pH, nutrients on the calcified algae.

10. To study the associated flora and fauna.

CHAPTER 2

DISTRIBUTION OF CALCIFIED ALGAE

INTRODUCTION

A certain number of algae enjoy a wide geographic distribution (Dignea simplex) while some are cosmopolitan (Fosliella farinosa) but, majority of the forms are restricted to definite areas (Fritsch, 1945). As far as the distribution of calcified algae is concerned, they are cosmopolitan and are exclusively marine except Charophytes (Chlorophyta) (Bold & Wynne, 1978). Almost all species of calcified algae favour warm waters with a few exceptions like some species of Corallina and Jania and also some crustose forms which grow only in the temperate environment (Johnson, 1961). Calcified members of Caulerpales i.e. Halimeda, Udotea, Penicillus are found only in the tropical and subtropical waters (Fritsch, 1945). Articulated corallines have a wide range from tropical to subtropical to temperate subarctic and arctic areas (Johansen, 1974). Padina, the only calcified Phaeophycean form favours tropical environment (Johnson, 1961). Dawson (1966), reported 50 living principle genera and approximately 649 species of calcareous algae. He tabulated 26 tropical and 24 temperate genera of calcified algae.

India with vast coastline, including two groups of oceanic islands i.e. Lakshadweep and Andamans and also several submerged banks harbour rich algal flora. In all, 624 marine algal species have been so far reported from the Indian coast (Untawale et. al., 1983). Out of these, 27 genera with 80 species are calcified forms. Boergesen (1930, 1937); Balakrishnan (1946, 1955); Chacko (1955); Desikachary (1956, 1957 & 1966); Desikachary and Balakrishnan (1957), Hillis (1959); Umamaheswara Rao (1969);

Srinivasan (1946, 1954 & 1960); Thivy (1959); Misra (1960, 1966); Untawale and Ambiye (1988) and Varma (1960) contributed towards taxonomy, ecology and distribution of calcified algae. Ganesan (1965, 1967) studied the species of Amphiroa, Jania, Arthrocardia for reproduction. Sundararajan (1984) described the calcified nemaliales. Jagtap (1987) studied the subtidal algal communities at Lakshadweep. Untawale et. al. (1989) explored the deep water flora of Angria, a submerged bank in the Arabian Sea.

In this chapter an attempt is made to study the distribution of calcified algae growing at different habitats like, mainland, oceanic islands,and the submerged banks of India. Floral affinities between the stations with diverse habitats of India is studied. Distribution of these algae with relation to the factors affecting distribution is also discussed.

II MATERIALS AND METHODS

A) Study Area : The species of calcified algae were collected from various localities of India (from 1985-1988). Field trips were undertaken to the coastal areas of Gujarat (Okha, Dwarka, Veraval, Beyt Shankhodhar, Porbandar, Pirotan), Maharashtra (Malwan, Ratnagiri), Goa (Anjuna, Baga, Cabo-de-Rama), Karnataka (Karwar, Bhatkal, Honawar), Kerala (Trivandrum), Tamil Nadu (Cape Comorin, Tuticorin, Mandapam, Pamban and also some coastal islands like Krusadai, Keelakarii, Pudumadam, etc.), Lakshadweep (Agatti, Bitra, Kalpeni, Kadmat, Kavaratti, Bangaram, etc.), Andamans (Corbyn's cove, Ross Island, New Vandoor, North Bay) (Fig. 1). Submerged banks namely Angria, Sessostris, Cora-Divh, Bassas de-Pedro were also surveyed (Fig. 2,3).

B) <u>Mode of Collection</u> : The specimen were collected by hand picking, SCUBA diving and snorkeling. Dredging was undertaken at submerged banks at various depths ranging from 20-70 meters. Observations were made during 4 cruises of R.V. *Gaveshani* nos. 159 (December 1985), 169 (May 1986), 173 (October 1986) and 206 (December 1988). A bucket dredge (size 0.7 x 0.5 x 0.25 m) was used for collecting the samples along the pre-planned transects so that maximum surface area is represented.

C) <u>Cluster analysis</u> : Similarity between these stations within India of diverse habitats is studied by Czeknowski's Dissimilarity Coefficient (Clifford and Stephenson, 1975) using following formula :

formula - $$1-\left(\frac{2a}{2a+b+c}\right)$$

where,

a = number of groups present in both stations A & B.

b = number of groups present in A but absent in B.

c = number of groups present in B but absent in A.

The dissimilarity coefficient was calculated for every pair. The most similar stations were linked to form the first combined group and the dissimilarity coefficients were recalculated using the group average method. The process was continued until all the original samples were recombined into a single group. The result is presented in the form of dendrogram.

Data used for the cluster analysis is based on the field collection and the previous records (after 1930).

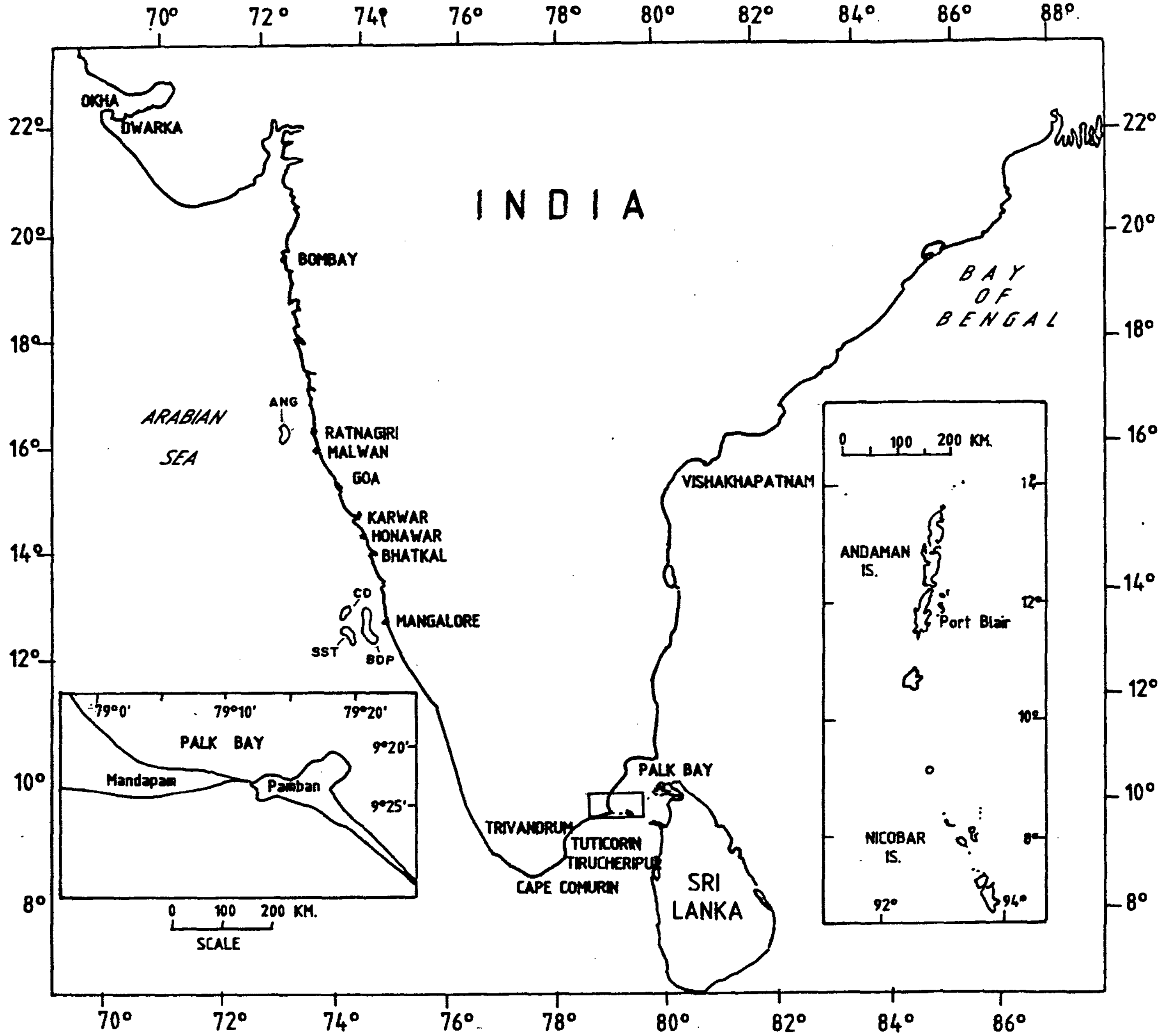


Fig. 1 MAP OF INDIA SHOWING STATIONS STUDIED

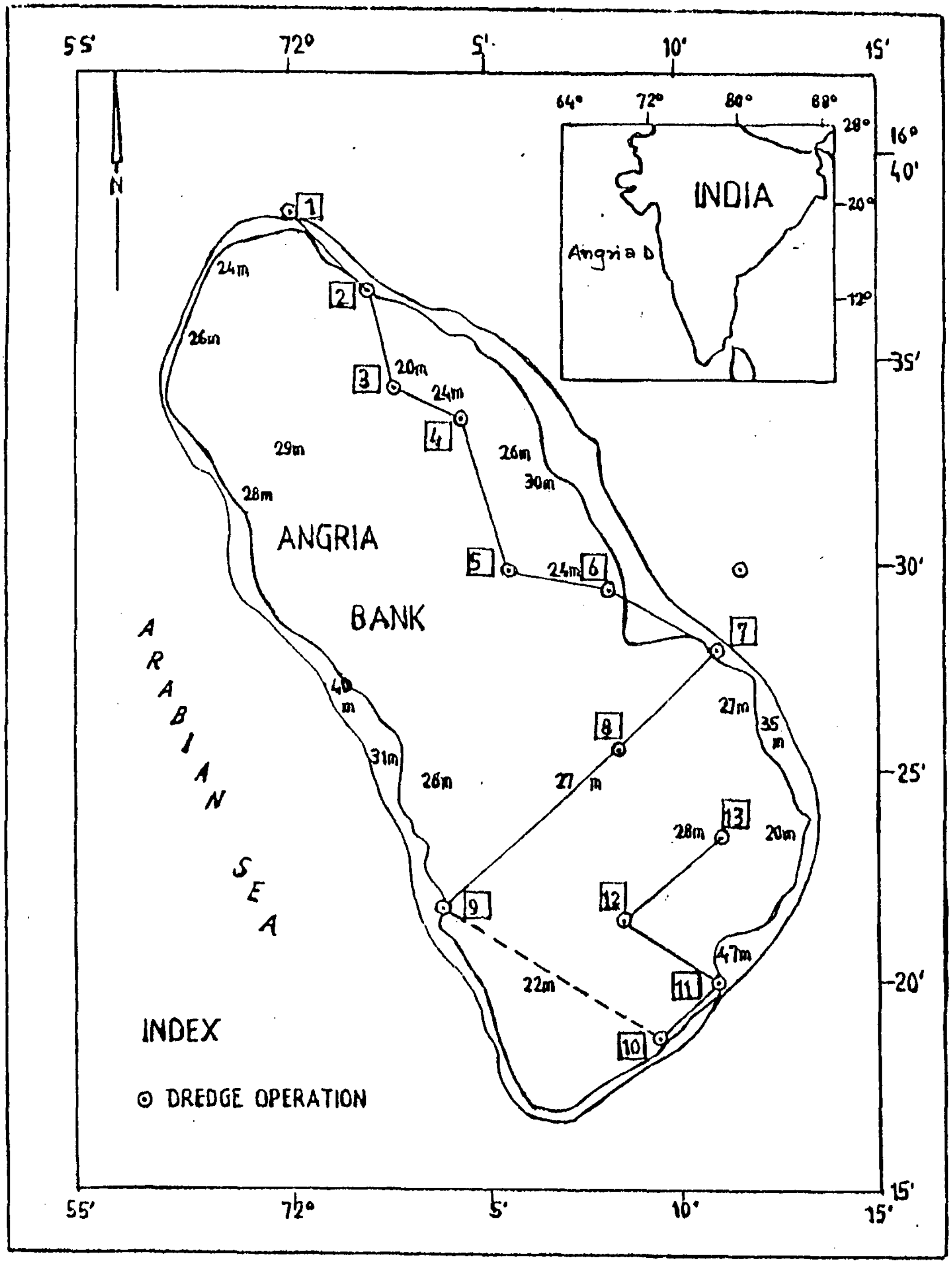


Fig. 2 Angria Bank in the Arabian Sea.

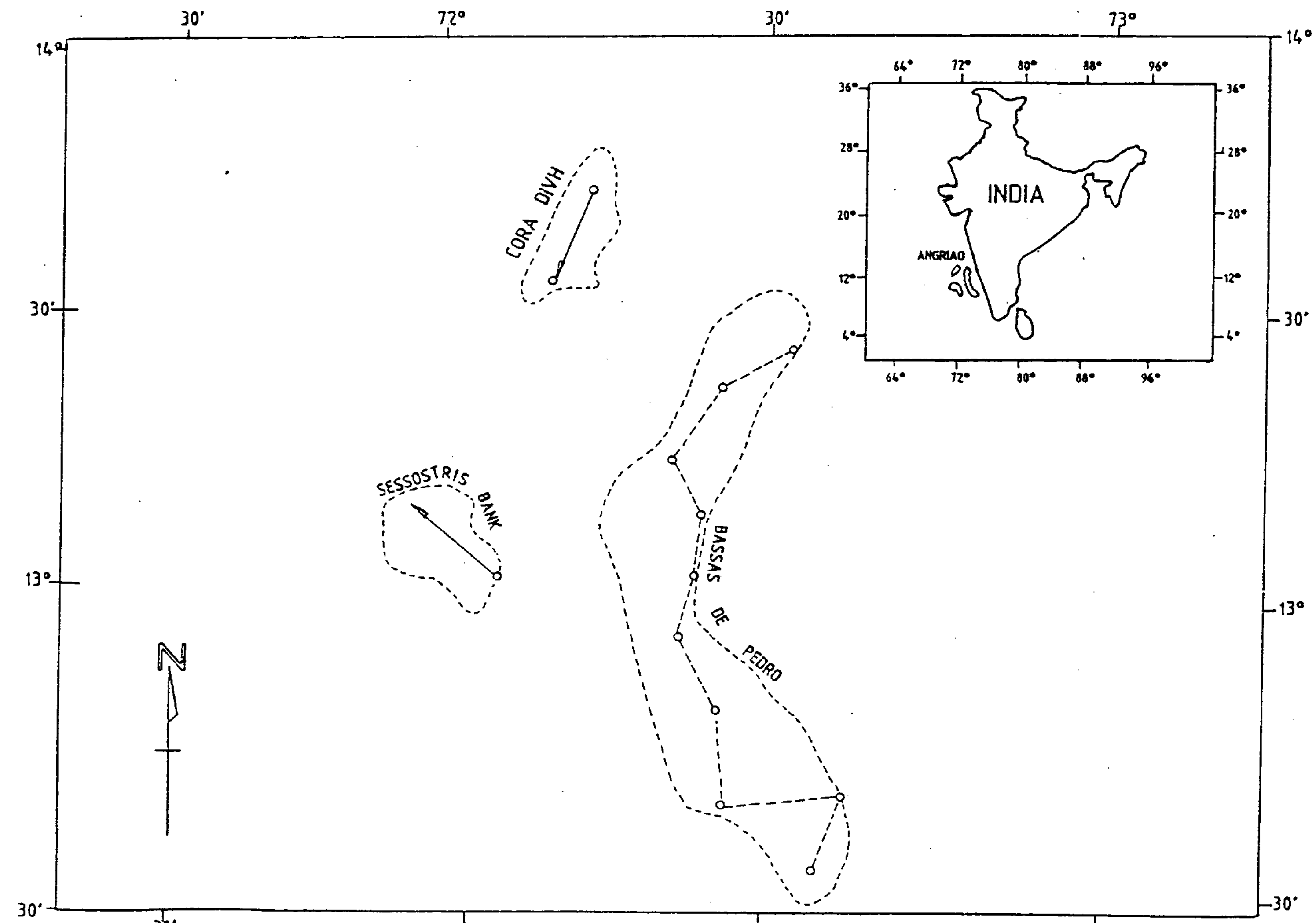


Fig. 3 BANKS IN THE ARABIAN SEA

III. RESULTS

A. Study areas and their features

a) Geology of Indian coast : Geology of the Indian coast is varied. Gujarat coast is composed of Deccan traps and the tertiary rocks. At some places, newer alluvium with limestones as well as miliolite forms known as "Porbandar stones" are of Pleistocene age. Central west coast is primarily composed of Deccan traps and rocks of green basalt which are glossy black and covered by calcareous surfaces. Further south, along the west coast upto Cape-Comorin, Archaen Gneiss, Schist and crustaceous sediments overlain by tertiary formations. Pure sandy stretches are frequent for greater or lesser distances along the entire east and west coast (Ahmed, 1972).

At Lakshadweep, there is compact but porous crust of lime stone conglomerate which is underlain by a bed of fine sand. Andaman and Nicobar Islands are fossiliferous consisting mainly of conglomerates, sand stones, lime stones and clay.

b) Topography : Rocky littoral region at Okha and Dwarka is almost flat and highly exposed area, sloping gradually towards sea and shows more or less a complete absence of rocky boulders with dead or living coralline substratum Veraval and Porbandar is more or less like Okha and Dwarka but shows lesser number of puddles and rock pools. Almost all places of central west coast, except Kerala show rocky and steep littoral zone with lesser intertidal expanse. Topography of these areas mostly shows boulders and most of the places have open shore habitats.

At Lakshadweep, upward growth of coral deposits has led to the development of coral reefs in the formation of atolls characterised by crescent shaped land, to the west of which lagoons occur. Shorelines of Andamans are highly indented and shallow. Coral reefs fringe most of the shores. There are frequent cases of raised coral reefs and other types of raised beaches. So, because of different morphological features this type of shoreline is described as compound shoreline (Ahmed, 1972). Diagrammatic representation of shore profiles is shown in Fig. 4.

c) Tidal data for the Indian coast and Archipelagoes : The highest and lowest values for the water marks recorded for Okha, Bombay, Karwar, Tuticorin, Pamban as well as for Lakshadweep and Andaman Island groups are shown in Table 2. Values for tidal ranges of the above mentioned localities were taken from the Admirality charts.

d) Climatology : Climatic conditions of India show three distinct seasons i.e. Premonsoon (February-May), Monsoon (June-September) and Postmonsoon (October-January). Values recorded for the rainfall and the air temperature are shown in Fig. 5 (Climatological Tables, 1960).

e) Hydrology : Tropical coastal habitats have warmer temperatures with less seasonal variation. Similarly, nutrients are also less in the tropical waters (Lubchencho and Gaines, 1982). Hydrological parameters like seawater temperature, salinity, dissolved oxygen and nutrients ($-NO_3$, $-NO_2$, $-PO_4$) show

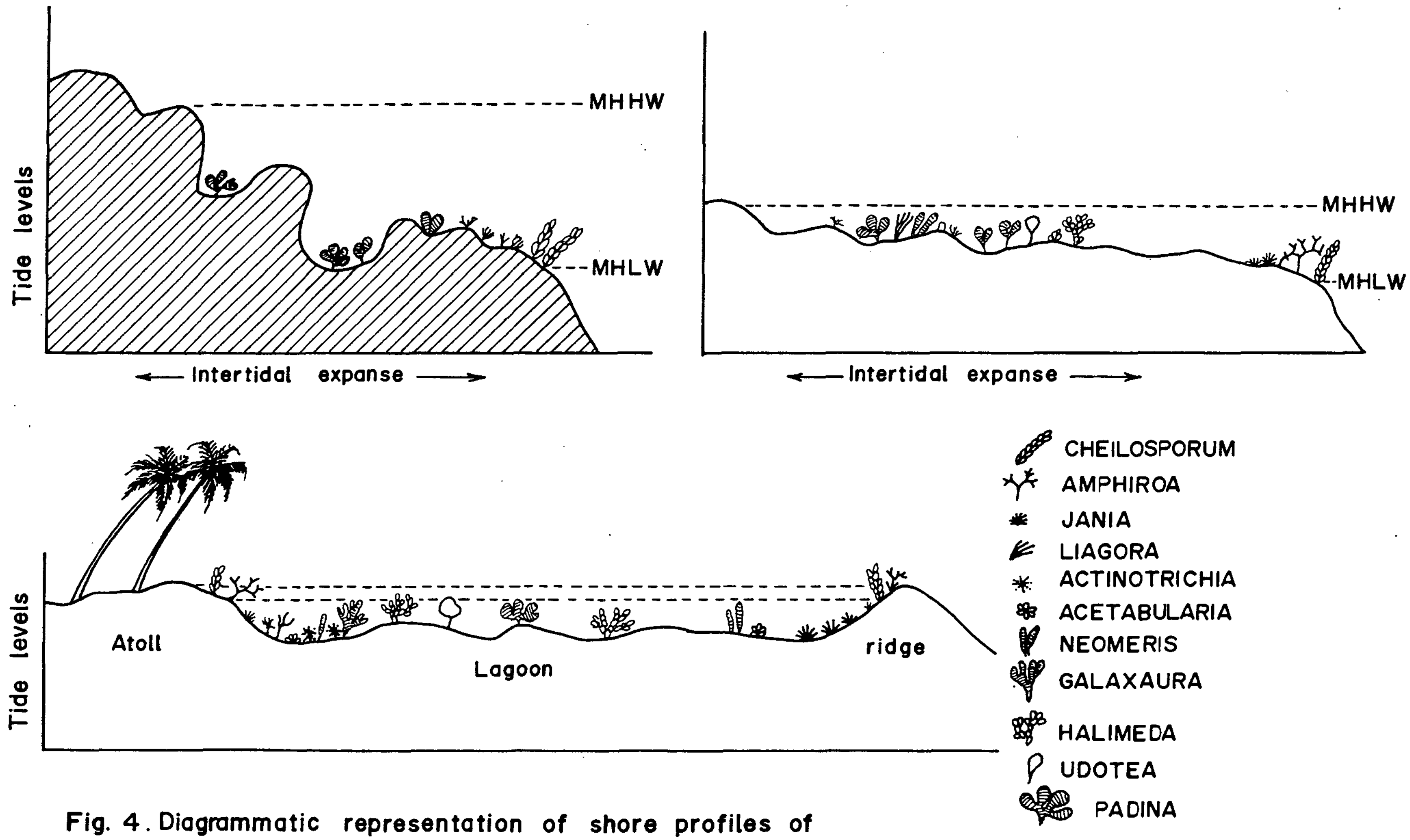


Fig. 4. Diagrammatic representation of shore profiles of Indian Coast

Table 2 : Tidal levels referred to Chart Datum*

Stations	Lat. ° (N)	Long. ' (E)	Height above datum (m)	
			MHHW	MHLW
1. Okha (Gujarat)	22‘28’	69‘05’	3.99	(-) 0.01
2. Bombay (Maharashtra)	18‘55’	72‘50’	4.96	(-) 0.03
3. Karwar (Karnataka)	14‘48’	74‘07’	2.27	(-) 0.01
4. Tuticorin (Tamil Nadu)	8‘17’	78‘12’	1.22	0.18
5. Pamban (Tamil Nadu)	9‘16’	79‘12’	0.96	(-) 0.01
6. Port Blair (Andamans)	11‘41’	92‘46’	2.45	(-) 0.02
7. Kavaratti (Lakshadweep)	8‘17’	73‘03’	1.74	0.17

* Compiled from the admirality charts

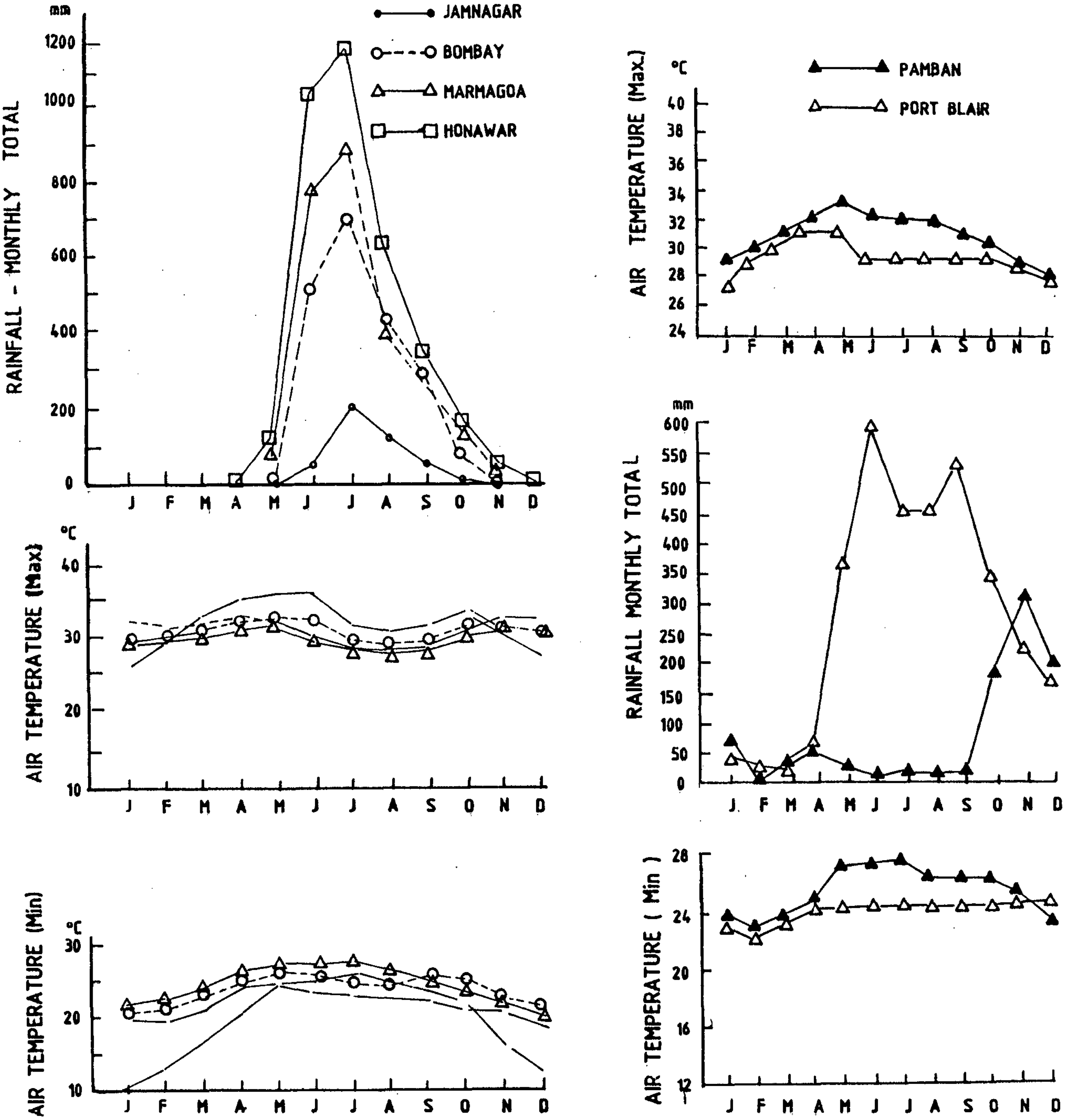


Fig. 5 CLIMATIC CHANGES ALONG THE INDIAN COAST.

uniformity in the seasonal distribution. Generally, the temperature, salinity and dissolved oxygen values are lesser during monsoon (June-September) and then increase gradually.

Hydrological observations at Angria bank were made by Nair et. al., (1966) where the midwater temperature was found to be 24.8 to 27.8 °C while salinity fluctuated between 35-36‰ Dissolved oxygen values ranged from 5-7 $ml.l^{-1}$ while phosphate values varied from 1.6 to 9.7 µg $at.l^{-1}$.

According to Anand et. al., (1968) average temperature in the shelf waters off Mangalore (where Sessostris, Bassas de Pedro, and Cora-Divh are located) is approximately 23 °C while dissolved oxygen concentration is 1 $ml.^{-1}$ at 75 m depth. PO_4 values ranged from 0.4 - 0.6 µg $at.l^{-1}$ at 25 m depth while salinity was 35.3‰ (Reddy and Sankaranarayan, 1968).

B) Distribution of calcified algae along the Indian coast

On the basis of present study and earlier records available, number of calcified algae from different groups are estimated as follows

Chlorophyta	7 genera	20 species
Phaeophyta	1 genus	3 species
Rhodophyta	9 genera	26 species

This makes up total of 17 genera with 49 species of calcified algae. Distribution of calcified algae in various taxa is shown in Table 3. General habitat of these forms is given below.

Table 3 - Distribution of calcified taxa in major groups

Algal groups	Family	Genera	Species
Chlorophyta	Udoteaceae	4	13
	Dasycladaceae	3	7
Phaeophyta	Dictyotaceae	1	3
Rhodophyta	Chaetangiaceae	2	7
	Dermonemataceae	1	1
	Helminthocladiaceae	2	10
	Corallinaceae	4	8

Total : 17 genera, 49 species

a) General Habitat of Calcified Algae :

Halimeda spp., Udotea flabellum were observed to be growing at depths of about 25-50 meters. Species like Halimeda gracilis fairly grows in the lagoons. Most of these forms favour sandy or coralline substrata. Halimeda tuna was found to be associated with Udotea indica growing on the small pebbles in the sandy area mixed with silt in the intertidal region. Halimeda tuna f. platydisca was found only in the deep water area. Neomeris annulata and many species of Acetabularia (Dasycladales) were quite often observed growing on the same rock, and mostly on the underside of rocks. N. annulata was also collected from the depth of 22 meters from Angria and Sessostris banks.

Padina sp. (Dictyotales) mostly grows in the rock pools and puddles on muddy or sandy substrata in calm waters. P. pavonica was also found at places where the domestic sewage was discharged. Species of Padina were found mostly growing in the intertidal areas and also in the lagoons as well as in submerged banks from the depth of about 25-31 meters.

Species of Galaxaura were collected from the intertidal areas and also from the deeper waters (20-50 meters) growing in the crevices of calcareous rocks or on dead corals. Actinotrichia fragilis was found to be growing on the calcareous rock crevices. As far as the articulated corallines are concerned, they were observed growing luxuriantly in the lower midlittoral zone on rocky substratum and at the places where the light is fairly bright and observed to withstand heavy wave action. Amphiroa anceps, Jania rubens were collected from the depth of about 18-31 meters. At most of the places, Amphiroa fragilissima was found growing on a zoanthoid Gemmaria sp. Details of habitat is given in Chapter III along with the description of species.

b) Calcified flora

Taking into consideration the geographical position, calcified flora is grouped into :

i. Flora of coastline/mainland

ii. Flora of Oceanic Islands

iii. Flora of submerged banks

Total number of calcified algae of these habitats is shown in Fig. 6.

i. Flora of the coastline/mainland

Present investigations on the south east coast of India were mainly concerned with the part of coastal regions lying between Madras and Cape Comorin and also along the coastal islands. East coast of India supports rich algal flora compared to the west coast. Altogether, 12 genera with 31 species were collected from this area. 5 genera with 11 species of chlorophyceae represent 35.48 % of the total calcified algae along this coast. The genus Padina (Phaeophyceae) with its three species represent 9.67% . Rhodophyta makes 54.85 % of total calcified species of the east coast of India.

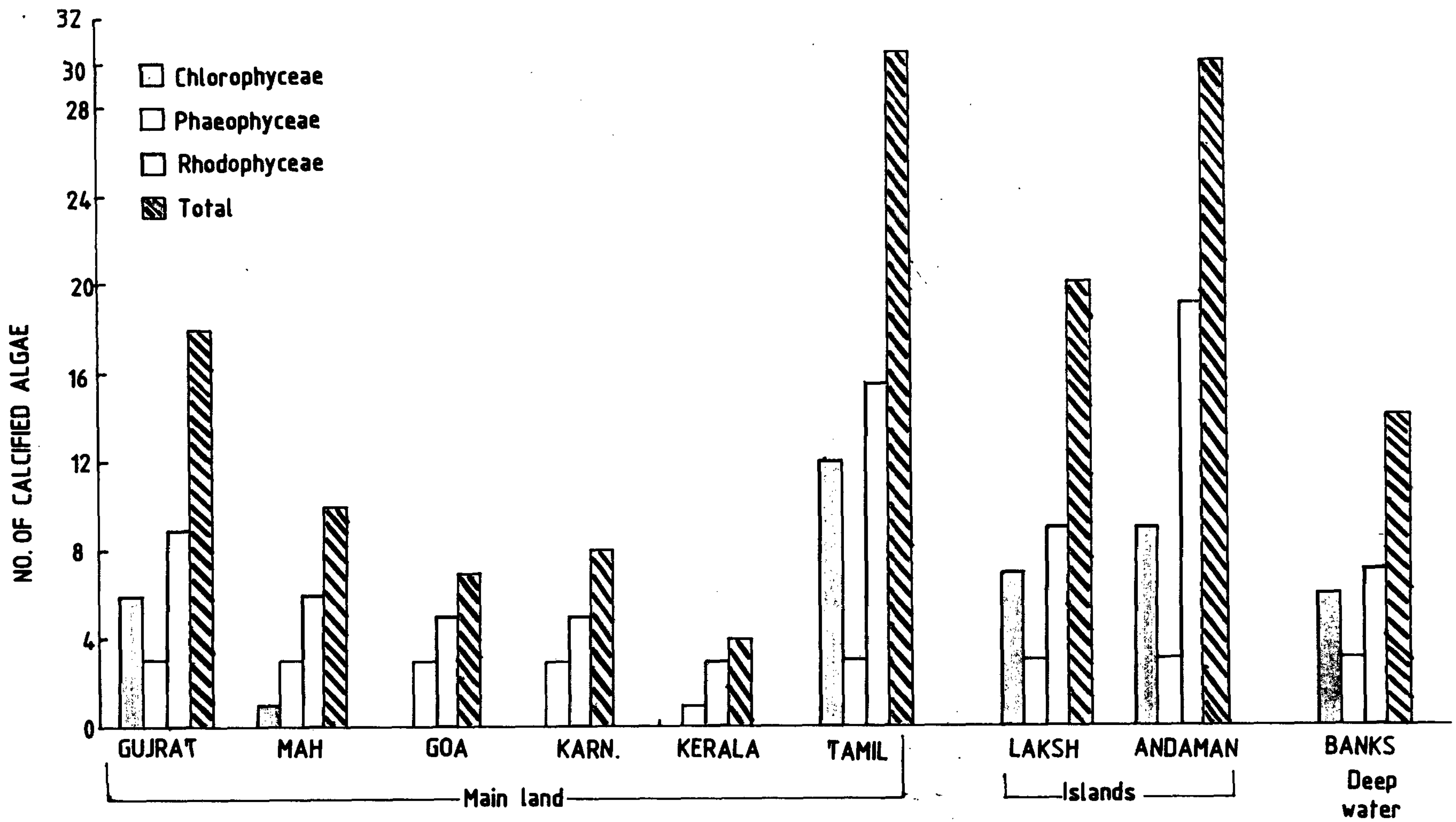


Fig. 6 Distribution of calcified algae along the Indian coasts, islands and banks

West coast of India showed the presence of 11 genera with 18 species, of which Chlorophyceae represents 33.33 % of the total calcified algae. *Padina* sp. (Phaeophyceae) represents 16.67 % while 6 genera with 9 species of Rhodophyta represent 50% of the total species.

Udotea javensis, *Penicillus manarensis*, *Neomeris dumetosa* (Chlorophyceae), *Galaxaura fastigiata*, *G. lenta*, *Liagora doridis*, *L. farinosa*, *L. erecta*, *L. manarensis*, *L. orientalis*, *L. viscida*, *Jania iyengarii* (Rhodophyta) were found to be endemic to the east coast of India.

Udotea indica (Chlorophyceae), *Galaxaura oblongata*, *Arthrocardia capensis* (Rhodophyceae) were observed to be confined only to the west coast of India.

Halimeda tuna, *Udotea flabellum*, *Acetabularia calyculus*, *A. parvula*, *Neomeris annulata* (Chlorophyceae), *Liagora ceranoides*, *Amphiroa* spp., *Cheilosporum spectabile* were observed to be common along the east and west coast of India.

Distribution of calcified algae along the coastal places of algal interest is shown in Table 4.

ii. Flora of Oceanic groups of Islands

Both the groups of oceanic islands i.e. Lakshadweep and Andamans support varied calcified flora.

Altogether 13 genera and 31 species of calcified algae grow along the Andaman group of islands. Compared to Lakshadweep, Andaman Islands support rich and varied flora. Chlorophyceae with 10 species of 5 genera (32.25%), 1 genus with 3 species of Phaeophyceae (9.67%), 8 genera with 17 species of Rhodophyceae (62.08%) represent the calcified flora of Andamans.

Halimeda simulans, Tydemania expeditionis, Acetabularia kilneri, Dasycladus ramosus (Chlorophyceae), Galaxaura fastigiata, Dotyophycus corymbosus, Liagora indica, Liagoropsis schrammi (Rhodophyceae) were confined to the Andaman Islands. Acetabularia kilneri J. Ag. (Chlorophyceae - Dasycladales) is the first record along the Indian coast.

Calcified flora of Lakshadweep includes 10 genera and 20 species of which 3 genera with 7 species of Chlorophyceae represents 35% of total calcified species. Phaeophyceae with 1 genus and 3 species contribute 15% while Rhodophyceae with 6 genera and 9 species contribute 50% of the total calcified flora of Lakshadweep.

Neomeris van-Bosseae (Chlorophyceae-Dasycladales) was observed to be endemic to Lakshadweep Islands and is the first record along the Indian coast.

Halimeda gracilis, H. opuntia, Acetabularia parvula, Neomeris annulata, Padina spp., Actinotrichia fragilis, Galaxaura rugosa, G. lapidescens, G. lenta were observed to be common for both the islands.

Distribution of calcified algae along these islands is shown in Table 4.

Table 4 : Distribution of calcified algae along the coastal places and oceanic islands.
(Compiled from Balakrishnan et. al., 1974; Iyengar, M.O.P., 1984 ; Krishnamurthy and Joshi, 1970; Krishnamurthy and Thomas, 1975; Krishnamurthy and Sundararajan, 1986, 1987; Patel and Francis, 1970) .

Sl.No.	Name of Alga	Gujarat	Maharashtra	Goa	Karnataka	Kerala	Tamil Nadu	Lakshadweep	Andamans
	CHLOROPHYTA								
1.	Halimeda discoidea Decaisne	-	-	-	-	-	-	-	+*
2.	H. gracilis Harv. ex. J.Ag.	-	-	-	-	-	+*	+	+*
3.	H. macroloba Decaisne	-	-	-	-	-	+*	-	+*
4.	H. opuntia Lamour	-	-	-	-	-	+	+	+
5.	H. simulans Howe	-	-	-	-	-	-	-	+
6.	H. tuna (Ell.et.Sol.) Lam.	+*	-	-	-	-	+*	+	+*
7.	H. tuna f. platydisca (Decaisne) Boerg.	-	-	-	-	-	-	-	-
8.	Penicillus manarensis (Krishnamurthy & Thomas)	-	-	-	-	-	+*	-	-
9.	P. sibogae A&E.S. Gepp	-	-	-	-	-	+*	-	-
10.	Tydemania expeditionis W.V. Bosse	-	-	-	-	-	-	-	+
11.	Udotea flabellum Howe	+*	-	-	-	-	+*	-	-
12.	U. indica A&E.S. Gepp	+*	-	-	-	-	-	-	-
13.	U. javensis A&E.S. Gepp	-	-	-	-	-	+*	-	-
14.	Acetabularia calyculus Quoit et. Guimard	+*	-	-	-	-	+*	+	+
15.	A. kilneri J. Ag.	-	-	-	-	-	-	-	+

16. *A. möebii* Solms-Laubach	+*	+*	-	-	-	+*	+	+
17. *Dacycladus ramosus* Iyengar	-	-	-	-	-	-	-	+*
18. *Neomeris annulata* Dickie	+*	-	-	-	-	+*	+	+
19. *N. dumetosa* Lamour	-	-	-	-	-	+*	-	-
20. *N. van-Bosseae* Howe	-	-	-	-	-	-	+	-
PHAEOPHYTA								
21. *Padina tenuis* Bory Thivy ex. Taylor	+*	+	-	+	-	+*	+	+
22. *P. gymnospora* (Kuetz) Vickers.	+*	+	+	+	+	+*	+	+
23. *P. pavonica* (L.) Thivy ex. Taylor	+*	+	+	+	+	+*	+	+
RHODOPHYTA								
24. *Actinotrichia fragilis* (Forsk.) Boergs.	-	-	-	-	-	+*	+	+
25. *Galaxaura fastigiata* Decaisne	-	-	-	-	-	+*	-	+*
26. *G. lapidescens* (Ell. et. Sol.) Lam.	-	-	-	-	-	-	+	+*
27. *G. lenta* Kjellman	-	-	-	-	-	+*	+	+
28. *G. marginata* Lamour	-	-	-	-	-	-	+	+*
29. *G. oblongata* Lamour	+*	-	-	-	-	-	+	+
30. *G. rugosa* Lamour	-	-	-	-	-	-	+*	+
31. *Dotyophycus corymbosus* Sundararajan	-	-	-	-	-	-	-	+*
32. *Liagora ceranoides* Lamour	+*	-	-	-	-	-	-	+*

33.	*L. doridis* Zeh	-	-	-	-	-	+*	+	+
34.	*L. erecta* Zeh	-	-	-	-	-	+*	-	-
35.	*L. farinosa* Lamour	-	-	-	-	-	+*	-	-
36.	*L. indica* Sundararajan	-	-	-	-	-	-	-	+*
37.	*L. mannarensis* Sundararajan	-	-	-	-	-	+*	-	-
38.	*L. orientalis* J. Ag.	-	-	-	-	-	+*	-	-
39.	*L. viscida* (Forsk.) Lamour	-	-	-	-	-	+*	-	+
40.	*L. visakhapatnamensis* U. Rao	-	-	-	-	-	+*	-	-
41.	*Liagoropsis schramii* (Maze et. Schram.)	-	-	-	-	-	-	+*	-
42.	*Amphiroa anastomosans* W.V. Bosse	-	-	-	-	-	+*	-	+
43.	*A. anceps* (Lamk.) Decaisne	+*	+	+	+	-	+*	+	+
44.	*A. foliacea* Lamour	-	+	+	+	-	+*	-	-
45.	*A. fragilissima* (L.) Lam.	+	+*	+	+	+	+*	+	+
46.	*Arthrocardia capensis* (Leach) Areschoug	+*	+	-	-	-	-	-	-
47.	*Cheilosporum spectabile* Harvey	+	+*	+	+	+	+	+	+
48.	*Jania iyengarii* Ganesan	-	-	-	-	-	+*	-	-
49.	*J. rubens* (L.) Lamour	+*	+*	+	+	+	+	+	+

* New record for the respective localities.

iii. Flora of submerged Banks :

Survey of different banks in the Arabian sea viz. Angria, Bassas-de-Pedro, Cora-Divh, Sessostris banks showed the presence of rich marine algal flora which includes 7 genera and 14 species of calcified algae. These forms were observed to be growing luxuriantly at various depths ranging from 18-70 meters. 3 genera and 6 species of Chlorophyceae, 1 genus and 1 species of Phaeophyceae and 3 genera and 7 species of Rhodophyceae represent the deep water calcified flora.

Halimeda gracilis, *H. discoidea*, *H. tuna* f. *platydisca*, *Galaxaura lenta*, *G. marginata*, *G. rugosa*, *G. oblongata*, *Udotea flabellum* were observed to be growing luxuriantly at these banks.

Calcified algae from these banks with their respective depths of occurrence are listed in the Table 5.

c) Cluster analysis :

Fig. 7 shows three clusters. The first cluster includes 4 areas i.e. Gujarat, Tamil Nadu, Lakshadweep and Andamans in which there is subclustering in between Gujarat and Tamil Nadu and between Lakshadweep & Andamans.

Second cluster includes 4 regions, Maharashtra, Goa, Karnataka & Kerala showing subclustering between Maharashtra & Goa and between Karnataka & Kerala.

Third cluster shows all the 4 stations of submerged banks i.e. Angria, Bassas-de-Pedro, Sessostris and Cora-Divh. There are two sub-clusters, one is of Angria and Sessostris and another is of Bassas-de-Pedro and Cora-Divh.

Table 5. Distribution of Calcified Algae from Submerged Banks

No.	Name of Alga	Bank	Depth Range (m)
	CHLOROPHYTA		
1.	*Halimeda discoidea*	Ang, BdP, SSt. CD	20 to 50
2.	*H. gracilis*	Ang, BdP, SSt. CD	20 to 50
3.	*H. tuna. f. platydisca.*	Ang, BdP, SSt.	18 to 68
4.	*Udotea flabellum*	SSt.	31
5.	*U. indica*	Ang.	22
6.	*Neomeris annulata*	Ang.	31
	PHAEOPHYTA		
1.	*Padina pavonica*	Ang., SSt.	31
	RHODOPHYTA		
1.	*Galaxaura lapidescens*	Ang.	22
2.	*G. lenta*	Ang. BdP	22 to 40
3.	*G. marginata*	Ang., SSt.,	18 to 31
4.	*G. oblongata*	Ang., SSt.,	18 to 31
5.	*G. rugosa*	Ang., SSt.,	18 to 31
6.	*Amphiroa anceps*	Ang., SSt.,	18 to 31
7.	*Jania rubens*	Ang., SSt.,	18 to 31

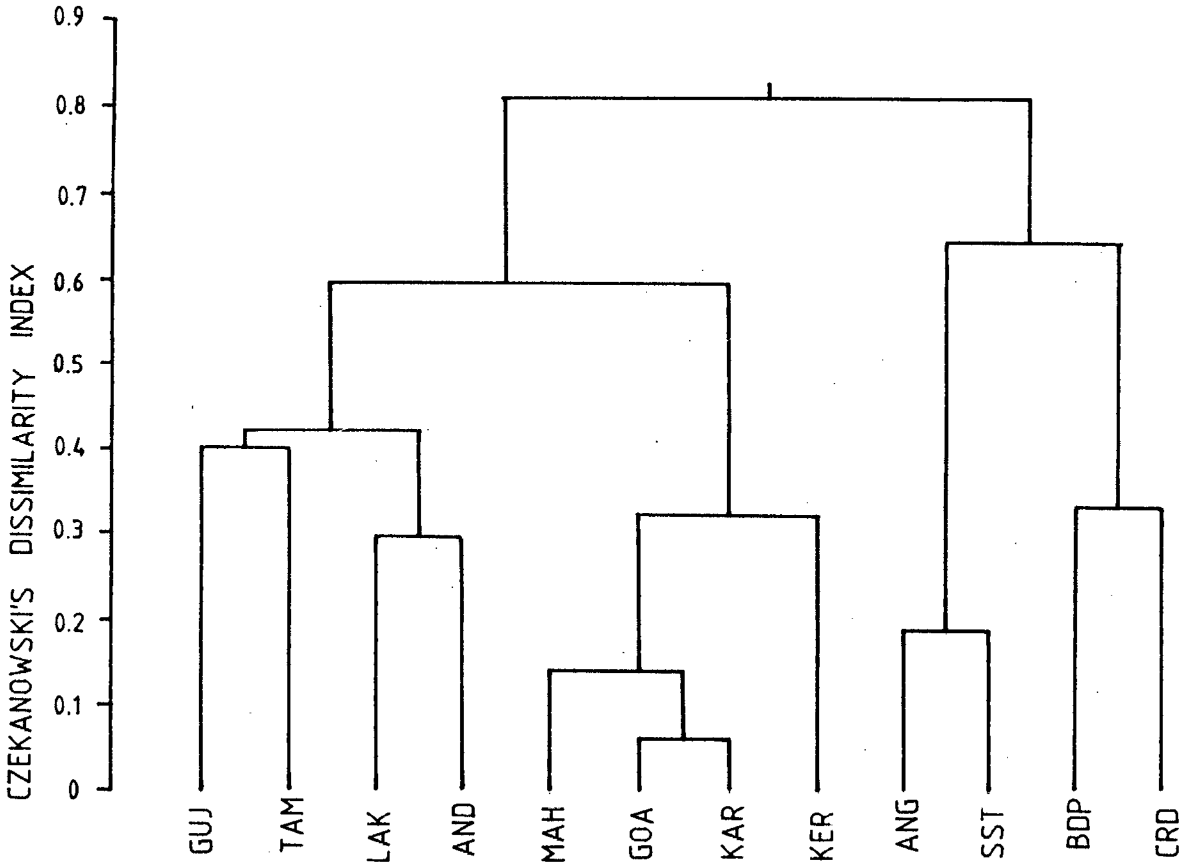


Fig. 7 Dendrogram showing floral affinities between stations.

IV) DISCUSSION

Study of the distribution pattern is important as it gives the information regarding spatial occurrence of organisms and also about their adaptations to the environment. According to Stephenson and Stephenson (1949), algal species show a wide variety of habitats and algal life forms and they are affected by the combined effect of a degree of wave action and nature of substratum. Calcified flora of India is divided into coastline flora, Oceanic Island flora and flora of the submerged banks based on their diverse habitats. Coastlands are the places which are subjected to heavy wave action, temperature variation and dessication. Such habitats are found to support luxuriant growth of articulated corallines which include the forms like *Amphiroa*, *Jania*, *Cheilosporum* and *Arthrocardia*, etc. As these forms have noncalcified flexible joints, they have ability to bend and withstand drag caused by wave action (Fritsch, 1945). According to Johnson (1961), these algae need fairly brilliant light and can withstand slightly higher temperature. Pearse (1972) proved that light stimulates the rate of accretion in these plants. Dense growth of articulated corallines in the surf zone along the coastal places and on the algal ridges of the exposed fronts of coral reefs can also be correlated with the supply of nutrients. Splashing of water must be giving the wetting effect to save them from the complete desiccation. Evans (1947) also found the positive correlation between the exposure and abundance of articulated corallines. Very poor growth of articulated corallines at submerged banks in the Arabian Sea can be correlated with such conditions.

Occurrence of species like Liagora, Galaxaura oblongata in the intertidal rock pools indicate that these algae favour protected environment. Rock pools are the places which are subjected to the hypersaline conditions, as they receive seawater only from the wave splash. As these sites are protected, accumulation of detritus causes the nutrient regeneration and so there is increase in the growth rate of algae. Harisson (1978) proved that there is 50% increase in the growth of Ulva sp. in the rock pool community than the control. Untawale et. al. (1979) also observed luxurient growth of Caulerpa sp. from the rock pools at Ratnagiri (Maharashtra). Hypersalinity of the rock pools does not affect the growth of nemaliales (Munda, 1978). Similar effects may be encountered in the shallower areas like lagoons and so must be favoured by Liagora, Galaxaura, Padina, etc.

As far as the coral reefs are concerned, algal ridges, reef flats and lagoons are the places of algal interest. Algal ridges which usually face seaward side, are subjected to the wave action. Algal ridges were observed to support the growth of articulated corallines as they can withstand drags caused by wave action. Flora of the reef flat and lagoons was found to be much similar. Rocky puddles and pools in the reef flats and lagoons, due to reduction in the wave action and sandy substratum support the growth of the species of Halimeda, Penicillus, Udotea, which were mainly associated with the species of Caulerpa, Bryopsis, Padina, Laurencia and Boergesenia (Jagtap, 1987). In such areas, growth of articulated corallines was observed rarely.

Similarities between flora of lagoons and deep waters can be discussed with the help of a theory put forward by Milliman and Emery (1968). According to them, Holocene transgression of the sea resulted in the rise of sea level occurred at the rate of about 1 to 1.3 $cm.yr^{-1}$. According to Nair & Qasim (1978), this rise in the sea level is applicable to the entire western continental margin of India, resulting into the submergence of coral reefs. Suitable substratum like sand and heads of dead corals and the clear water support the growth of Dasyclads and Caulerpales. Untawale et. al., (1989) showed the similarity between the flora of Lakshadweep and submerged banks. According to Nair & Qasim (1978), the outer shelf of the west coast of India is largely sandy and constantly in a state of motion and under the influence of waves, currents and tides. Therefore, mobility of the sediments would probably be the main inhibiting factor for the coral growth.

The result of the cluster analysis shows that there is a floral similarity between Gujarat (West Coast) and Tamil Nadu (East Coast) which is linked to the flora of Lakshadweep and Andamans. These localities i.e. Gujarat and Tamil Nadu show number of fringing reefs like Pirotan & Beyt Shankhodar from Gulf of Kuchchh and Keelakarii, Pudumadam, Krusadai from the Gulf of Mannar. Also there exists a close similarity between the topography of the littoral region and reef flat of these islands i.e. the steepness of the coastal slope, abundance of the rocky puddles and pools influence the marine algal flora. Fine silt occuring below the high water mark favours the growth of Halimeda sp. and Udotea sp. So also the rocky surfaces covered by the remains of dead corals exhibit the growth of Amphiroa, Jania and Arthrocardia in the intertidal belt. Algae growing in this belt are subjected to the complete exposure for some hours (Misra, 1960). But the rock pools are never subjected to the complete emergence and exposures supporting a better growth. So the rich flora is supported by the gently sloping littoral zone, having the extensive flat areas, broken by an abundance of rock pools and puddles. So also a suitable substratum like conglomerated rocks, boulders and pebbles overlain by the sandy mud and gravel support the algal growth.

Second cluster shows the similarity between Maharashtra, Goa, Karnataka and Kerala. Articulated corallines are the dominant species in these areas as they can withstand heavy wave action existing here.

Third cluster includes all the submerged banks. As there is no destruction by waves in this area, the sandy silty substratum and coralline rocks as also the clear water, support rich algal flora.

It will be easier to explain distribution with the help of many adaptations observed in the calcified algae to avoid grazing. Members of Nemalionales avoid grazing by producing short or alternating life histories eg. Liagora (Littler, 1980). According to Steneck and Walting (1982), colony formation in many algae acts as a structural defense and minimize accessibility for grazing, which is observed in articulated corallines and in Halimeda spp. Articulated corallines mostly grow luxuriantly in the wave break zone as the herbivores are known to be less in this area. Also the calcareous nature of the thallus make the alga unpalatable to the grazers. These algae are also reported to have low energy content (Littler, 1983).

According to Fenical (1980), synthesis of toxic secondary organics by algae increases in herbivore rich subtropical and tropical reef system. Abundance of calcified algae in the coral reef ecosystem can be discussed with the help of bioactive compounds present in them. Coral reefs are the most productive ecosystems, where the carbon fixed by algae enters the food chain via phytoplankton to zooplankton to crabs, molluscs, echinoderms and fish. Halimeda avoides grazing by producing deterent chemicals. Paul and Fenical (1984) reported diterpenoid trialdehyde, an icthyotoxic compound which shows antibiotic activity and inhibits cell division and sperm motility. Older thalli of Halimeda sp. contains Halimedatrial and Halimedatetra-acetate making the plant nutritionally useless but useful from the defense point of view. However, these chemicals are lacking in the younger tissues, so young plants are reported to grow at night when the herbivorous fish are inactive (Hay et. al. 1988). Most of the Udoteacean members are reported to be highly resistant to fish grazing (Lewis, 1985). Most of the algae avoid grazing by growing in shallow or deep water or in the areas of strong wave action where the herbivores are less (Borowitzka, 1981). Abundance of calcified algae at submerged banks can be correlated with this reason. According to Borowitzka (1981), partial exposing to the tidal cycle in case of many algae limits grazing time available to large herbivorous fish. Occurrence of _Actinotrichia_, _Galaxaura_ spp. in the rock crevices also make fishes unable to graze.

Amphiroa fragilissima and _Gemmaria_ are mostly found associated with each other. Biogenic amine is reported in both these organisms and it's occurrence is seasonal (Solimabi _et_. _al_., 1987). The zoanthoid contains this amine when it is absent in the alga and is devoid of it when present in the seaweed. According to Solimabi _et_. _al_. (1987), there might exist some symbiotic relationship between these organisms. It should be considered as an adaptation to avoid grazing by getting associated with toxic organisms.

As far as the present observations are concerned, the distribution of calcified algae belonging to various localities of diverse habitats of India is dependant on the submergence and emergence of water, wave action and on the topographical characteristics of each place and also on the nature of substratum. Biotic factor like grazing also affects the distribution pattern to which algae get adapted by various means.

CHAPTER 3

TAXONOMY

I. INTRODUCTION

Calcified algae not only show variation in type and degree of calcification but also in morphology. As mentioned in Chapter 1, algae with biochemically precipitated deposits of calcium carbonate comprise an artificial assemblage which cuts across all taxonomic boundaries. Distribution of calcified algae in various phyla is shown in Table I (see Chapter 1).

Hillis (1980), revised the genus *Halimeda* and placed a number of forms in synonym and discussed them in the text of pertinent species. She in 1959, gave an account of *H. discoidea*, *H. gracilis*, *H. macroloba* from Andamans and Krusadai. Boergesen (1930), studied *Udotea indica* from Okha. Chacko (1955), Patel and Francis (1970), Balakrishnan *et. al*. (1974) dealt with the distribution and taxonomic account of dasyclads. Ganesan (1965, 1967) deals with the study of articulated corallines. Balakrishnan (1955), Balakrishnan *et. al*. (1982), Desikachary (1957, 1966), Umamaheswara Rao (1969) and Sundararajan (1984) contributed towards the study of Indian nemaliales. Misra (1960), Thivy (1959) gave an account of *Padina* species.

Literature survey shows that, most of the calcified algae are just enlisted but very few are described for their morphological and anatomical features. Study of gross morphology is important as it gives information regarding the wide range of variation, in the appearance of species, which is based on the habitats where the alga grows.

This chapter covers the gross morphology and anatomy of 33 calcified algae which includes 14 species of Chlorophyceae, 3 species of Phaeophyceae and 16 Rhodophycean forms. It also includes the reproductive details of some forms.

II. MATERIALS AND METHODS

The species of calcified algae were collected from different localities of India (for localities and for mode of collection - see Chapter 2).

A) Preservation : Samples were preserved by both dry and wet methods i.e. by preparing herbaria and preserving in 4% seawater formalin and are deposited at the Marine Algal Reference Centre, National Institute of Oceanography, Goa.

B) Microscopic preparations

For studying *Halimeda* spp., histological preparations were made by removing narrow rectangular strip cut from the middle of internode of one segment to observe the cortical layer adjoining nodes. Sections were floated in water and decalcified with 25% HCl and mounted in glycerine.

To study nodal anatomy, adhered nodal filaments were teased. Transverse sections through node were taken to observe the pores between the adjacent medullary filaments.

For studying the reproductive and vegetative morphology of *Galaxaura*, *Actinotrichia*, *Liagora* tips of the branches were first decalcified with 1N HCl and followed by staining with Anilin blue. Decalcified material was then squashed for studying the details.

For articulated corallines like Jania, 'Susa' fixative was used (Suneson, 1937) while for Arthrocardia and Amphiroa, materials primarily preserved in 4% seawater formalin were refixed in Peryny's fluid. After complete decalcification, material was rinsed in 70% alcohol and placed in fresh 70% alcohol (Mason, 1953). Microtome sections were cut following usual procedure (Johansen, 1940). Sketches were made using prism type of Camera lucida.

III. RESULTS

In the following account, 14 species of Chlorophyta (9 species of Udoteales, 3 species of Dasycladales), 3 species of Padina (Phaeophyta), 15 species of Rhodophyta (9 species of Nemaliales, 6 species of Cryptonemiales) are described.

List of the species studied with the details of localities and period of collection is given in Table 6 and their systematic position is shown in Table 7.

A) CALCIFIED GREEN ALGAE

1. HALIMEDA Lamouroux

This is a heavily calcified, segmented alga with erect, flaccid, decumbent, prostrate habit, attached to the substratum by means of a single holdfast region (except as in H. opuntia). The photosynthetic portion of the plant is composed of variously shaped calcified internodes or 'segments' which are connected by narrow uncalcified flexible nodal region. Segments are ribbed, spherical, reniform with varying thickness. Degree of calcification varies influencing the colour of the plant.

Table 6 : List of the species described for their morphology, anatomy and reproduction.

	Species studied	Locality	Date of collection
	CHLOROPHYTA		
	Halimeda		
1.	*Halimeda discoidea*	Angria	01.06.1986
2.	*H. gracilis*	Agatti	06.12.1988
3.	*H. macroloba*	New Wandoor	30.04.1988
4.	*H. opuntia*	Kavaratti	07.12.1988
5.	*H. simulans*	New Wandoor	30.04.1988
6.	*H. tuna*	Okha	15.01.1986
7.	*H. tuna* f. *platydisca*	Sessostris	11.12.1988
	Udotea		
8.	*Udotea flabellum*	Angria	01.06.1986
9.	*U. indica*	Angria	01.06.1986
	Acetabularia		
10.	*A. calyculus*	Okha	15.01.1986
11.	*A. kilneri*	Corbyn's cove	04.05.1988
12.	*A. parvula*	Corbyn's cove	04.05.1988
	Neomeris		
13.	*N. annulata*	Corbyn's cove	04.05.1988
14.	*N. van-Bosseae*	Agatti	06.12.1988
	PHAEOPHYTA		
	Padina		
15.	*P. gymnospora*	Anjuna	30.12.1988
16.	*P. pavonica*	Okha	15.01.1986

Table 6 Contd.

17.	*P. tenuis*	Okha	15.01.1986
	RHODOPHYTA		
	Actinotrichia		
18.	*A. fragilis*	Agatti	06.12.1988
	Galaxaura		
19.	*G. lapidescens*	Angria	08.12.1988
20.	*G. lenta*	Angria	08.12.1988
21.	*G. marginata*	Sessostris	10.12.1988
22.	*G. oblongata*	Sessostris	10.12.1988
23.	*G. rugosa*	Angria	08.12.1988
	Liagora		
24.	*L. ceranoides*	Okha	15.01.1986
25.	*L. doridis*	Gulf of Mannar	25.01.1987
26.	*L. indica*	Gulf of Mannar	25.01.1987
27.	*L. visakhapatnamensis*	Krusadai	27.01.1987
	Amphiroa		
28.	*A. anastomosans*	Anjuna	25.02.1987
29.	*A. anceps*	Malwan	18.04.1987
30.	*A. foliacea*	Trivandrum	07.03.1986
31.	*A. fragilissima*	Anjuna	25.02.1987
	Arthrocardia		
32.	*A. capensis*	Malwan	10.04.1987
	Jania		
33.	*J. rubens*	Anjuna	14.02.1986

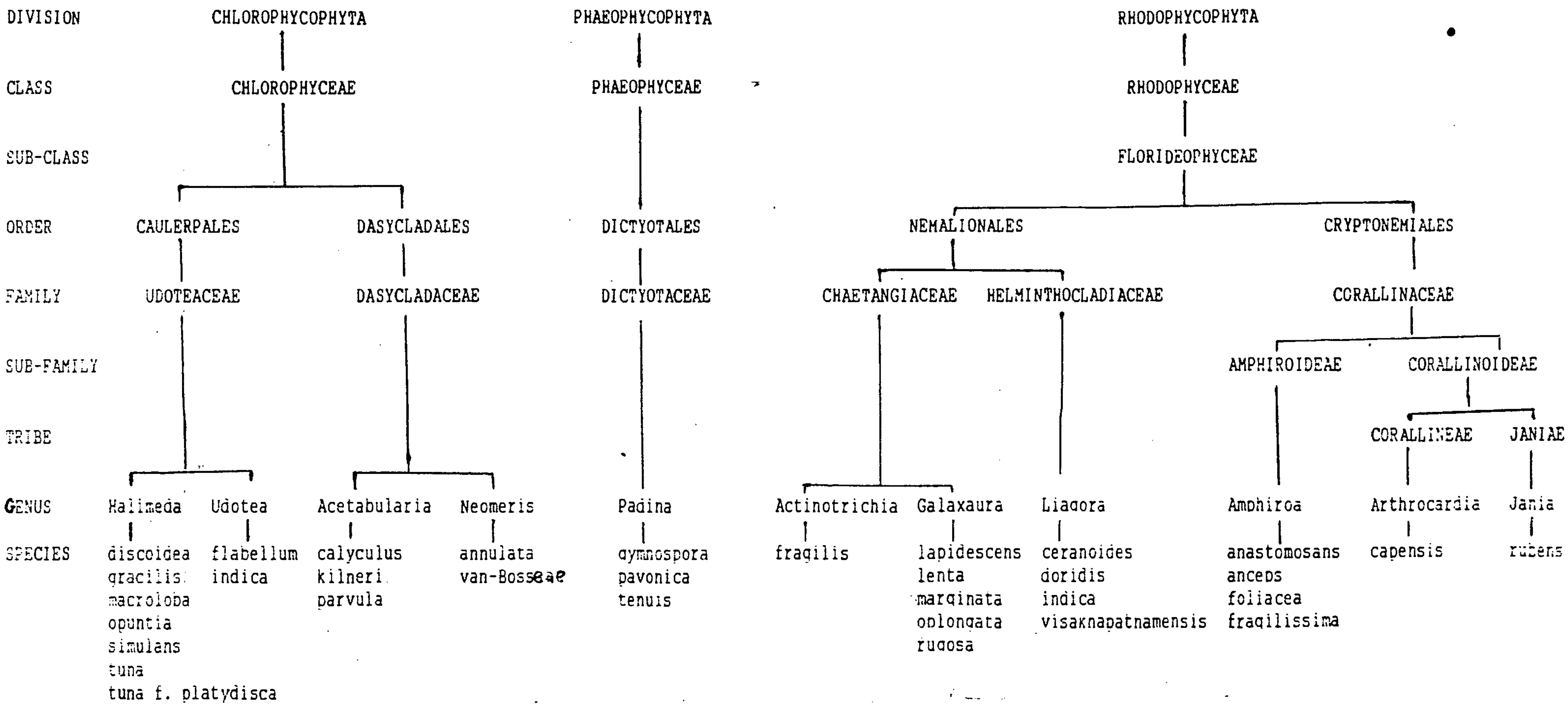


Table 7. Systematic positions of calcified algae studied. Adopted from Bold & Wynne (1978); Johansen (1969a) and Johansen & Silva (1978).

Interweaving of the siphons results into the multiaxial construction.

In the following account *H. discoidea*, *H. gracilis*, *H. macroloba*, *H. opuntia*, *H. simulans*, *H. tuna*, *H. tuna* f. *platydisca* are described.

a) *H. discoidea*
Decaisne

Hillis (1980), Fig.41, P.136-138.

Habit-Habitat : This alga grows on dead corals and on the small pebbles in shallow lagoons or at low tide mark and also at the depth of 25-50 meters.

Plants are loose to compact, having a small but distinct holdfast region, attaining a height of 18-20 cm. Segments are compressed discoidal to reniform with entire upper margin 25-30 mm long and 28-35 mm broad, and averaging 0.75-1.25 mm in thickness. Branching is di-, tri- or polychotomous (Plate I a).

Anatomy : Cortex consists of 2-3 layers of utricles. Surface diameter of peripheral utricles is 45-60 um (Fig. 8 a). Secondary utricles are well developed & 90-210 um broad (Fig. 8 b).

Nodal medullary filaments unite in twos or threes. Fusion is either complete or incomplete (Fig. 8 c).

b) *H. gracilis*
Harv. ex J. Ag.

Hillis (1980), Fig. 44, P. 144-147.

Habit-Habitat : Plants are straggling and sprawling, attaching to the sand or coralline rocks by multiholdfast system, occurs in the vertical range from -1 to -70 meters.

Plants are 40-50 cm in length, flaccid, straggling. Calcification is moderate to heavy. Colour upon drying is whitish green. Segments are ribbed, reniform with entire upper margin, 5-7 mm long, 12-15 mm broad and averaging 0.5-0.75 mm in thickness (Plate I b, c).

Anatomy : Cortex is made up of two to three layers of utricles (Fig. 8 e). The outermost utricles measure 22-65 um in surface view appear hexagonal to round (Fig. 8 d).

Nodal medullary filaments are mostly fused in twos (Fig. 8 f) but are also seen occasionally in threes.

c) *H. macroloba*
Decaisne

Hillis (1980), Fig. 28, P. 108-110.

Habit-Habitat : Mostly grows in the mud flats developing extensively flats in shallow waters. Thalli are whitish green, solitary, erect, with light to moderate calcification. Holdfast is massive and well developed extending upto 4-6 cm. Branching is mostly dichotomous but basal segments sometimes consolidate laterally. Segments are discoidal with entire upper margin.

Segments are 25-30 mm long, 30-35 mm broad and of 1-1.5 mm thickness (Plate I d).

Cortex is 2-4 layered. Outermost utricles separate after decalcification and have surface diameter of 44-62 um (Fig. 8 g). Secondary utricles are 20-58 um broad and 30-140 um long (Fig. 8 h).

Nodal medullary filaments unite as a single group. The adjacent filaments communicate by pores (Fig. 8 i). Cell walls in this area are thick and pigmented.

FIG. 8

Surface view, cortex and nodal medullary filaments of Halimeda discoidea Decaisne, H. gracilis Harv. ex. J. Ag. and H. macroloba Decaisne.

H. discoidea (a - c) :

a) Surface view

b) Cortex

c) Nodal medullary filaments

H. gracilis (d - f) :

d) Surface view

e) Cortex

f) Nodal medullary filaments

H. macroloba (g - f) :

g) Surface view

h) Cortex

i) Nodal medullary filaments

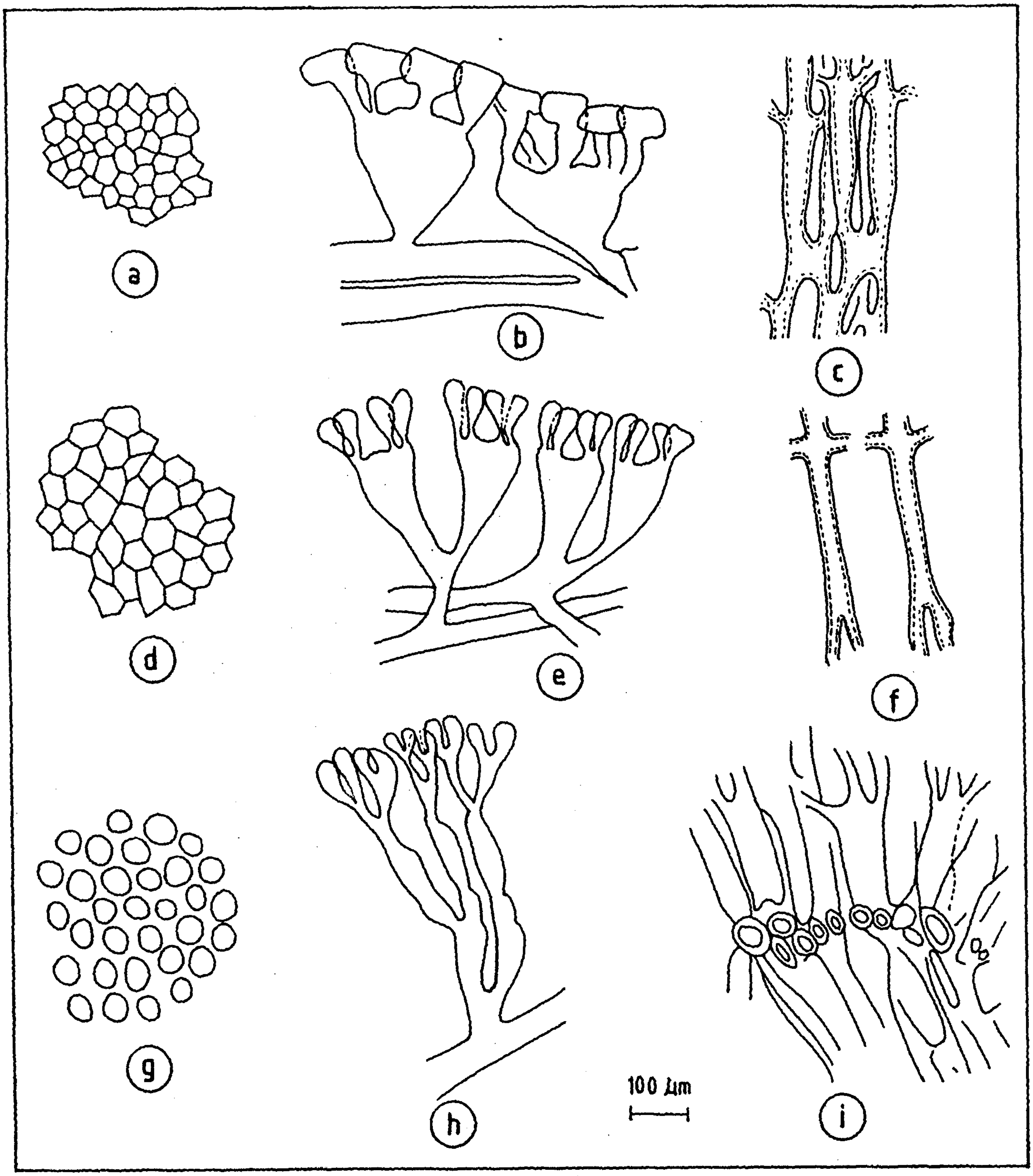


Fig. 8

d) *H. opuntia*
(L.) Lamouroux

Hillis (1980), Fig. 19, 51, 92; P. 110 - 112.

Habit-Habitat : This species is very common in the coral reefs. One which grows in the sandy areas forms dense patches and presents reniform, slightly larger segments; other forms grow at the coral ridge present loose and slightly smaller segments, triangular in shape.

Thalli are whitish green in colour, heavily calcified, spreading laterally to form large colonies, attaching at various points, without definite holdfast. Branching is irregular, overlapping. Thalli reach upto a height of 20-25 cm. Colour upon drying is golden or whitish. Segments are ribbed, oblong and oval to reniform in shape. Lower segments are deeply trilobed (Plate I e).

Cortex is composed of medullary filaments which branch dichotomously to form 3-5 layers of utricles (Fig. 9 b). The outermost utricles appear round to hexagonal in surface view and measure about 16-60 um in diameter (Fig. 9 a).

Nodal medullary filaments unite in pairs or remain separate (Fig. 9 c).

e) H. simulans
Howe.

Hillis (1980), Fig. 26, P. 103-105.

Habit-Habitat : Grows in sandy or muddy substrate forming cushion like clumps growing upto a height of 10-12 cm. Calcification is moderate to heavy. Holdfast is massive, well developed, 4-6 cm in height. Branching di-tetrachotomous. Segments are ribbed, reniform, entire, undulate or very shallowly lobed, 10-15 mm long, 15-18 mm broad and averaging 1 mm in thickness (Plate I f).

Anatomy : Cortex of two to four layers of utricles. Outermost utricles generally remain attached after decalcification, having an average diameter of 26-50 um. (Fig. 9 h). Each secondary utricle supports 2-4 primary utricles. Secondary utricles 25-78 u broad and 28-110 um long. Innermost utricles 33-90 um in width (Fig. 9 i).

Nodal medullary filaments unite as a single group and adjacent filaments communicate by pores (Fig. 9 j). Cell walls in this area are thick and pigmented.

f) H.tuna
(Ellis et Sol.) Lamour.

Hillis (1980), Fig. 35, P. 122-124.

Habit-Habitat : Plants mostly grow on the coralline, rocky and sandy substrata, associated mostly with Udotea.

Plants spreading or compact, 10-12 cm in height, with single inconspicuous holdfast. Calcification is moderate. Branching is mostly dichotomous. Segments are discoid to reniform, 10-12 mm long and 15-18 mm broad (Plate I g).

Anatomy : Cortex is made up of 2-4 layers of utricles (Fig. 9 e). Peripheral utricles measure 25-90 um in surface diameter (Fig. 9 d).

Nodal medullary filaments unite in twos, threes or remain separate or they are laterally adhered (Fig. 9 g).

g) H. tuna f. platydisca
Decaisne, Barton

Hillis (1980), P. 122-124.

Habit-Habitat : This alga is a deep water form, collected from a depth of 20-70 meters. Mostly found growing on dead corals and on small pebbles. Plants are 10-15 cm, loose with di-tri to polychotomous branching. Segments are discoidal, 25-30 mm long and 30-40 mm broad. Calcification is moderate. Segments have either entire or slightly wavy margin (Plate I f).

Anatomy : It is very similar to H. tuna except in having larger peripheral utricles which measure 40-100 um in diameter (Fig. 9 f).

This species is the first record for India.

FIG. 9

Surface view, cortex and nodal medullary filaments of Halimeda opuntia Lamouroux H. tuna (Ell. et Sol.) Lam. H. tuna f. platydisca Decaisne Barton, H. simulans Howe,

H. opuntia (a - c) :

a) Surface view

b) Cortex

c) Nodal medullary filaments

H. tuna (d - g) :

d) Surface view

e) Cortex

g) Nodal medullary filaments

H. tuna f platydisca

f) Cortex

H. simulans (h - j) :

h) Surface view

i) Cortex

j) Nodal medullary filaments

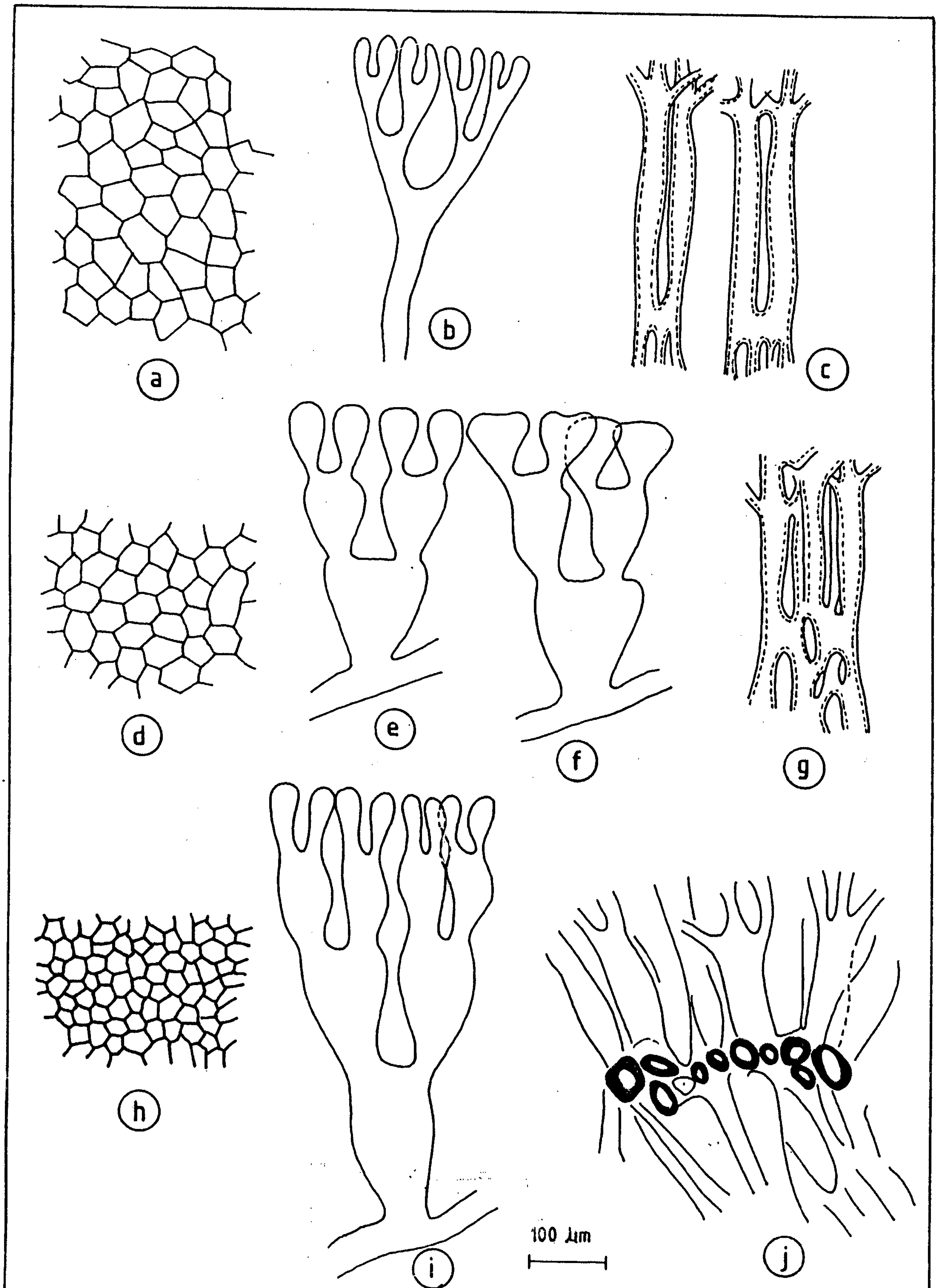


Fig. 9

PLATE I

a) *Halimeda discoidea* Decaisne

b,c) *H. gracilis* Harv. ex. J. Ag.

d) *H. macroloba* Decaisne

e) *H. opuntia* Lamour

f) *H. simulans* Howe

g) *H. tuna* (Ell. et. Sol.) Lam.

h) *H. tuna* f *platydisca* Decaisne

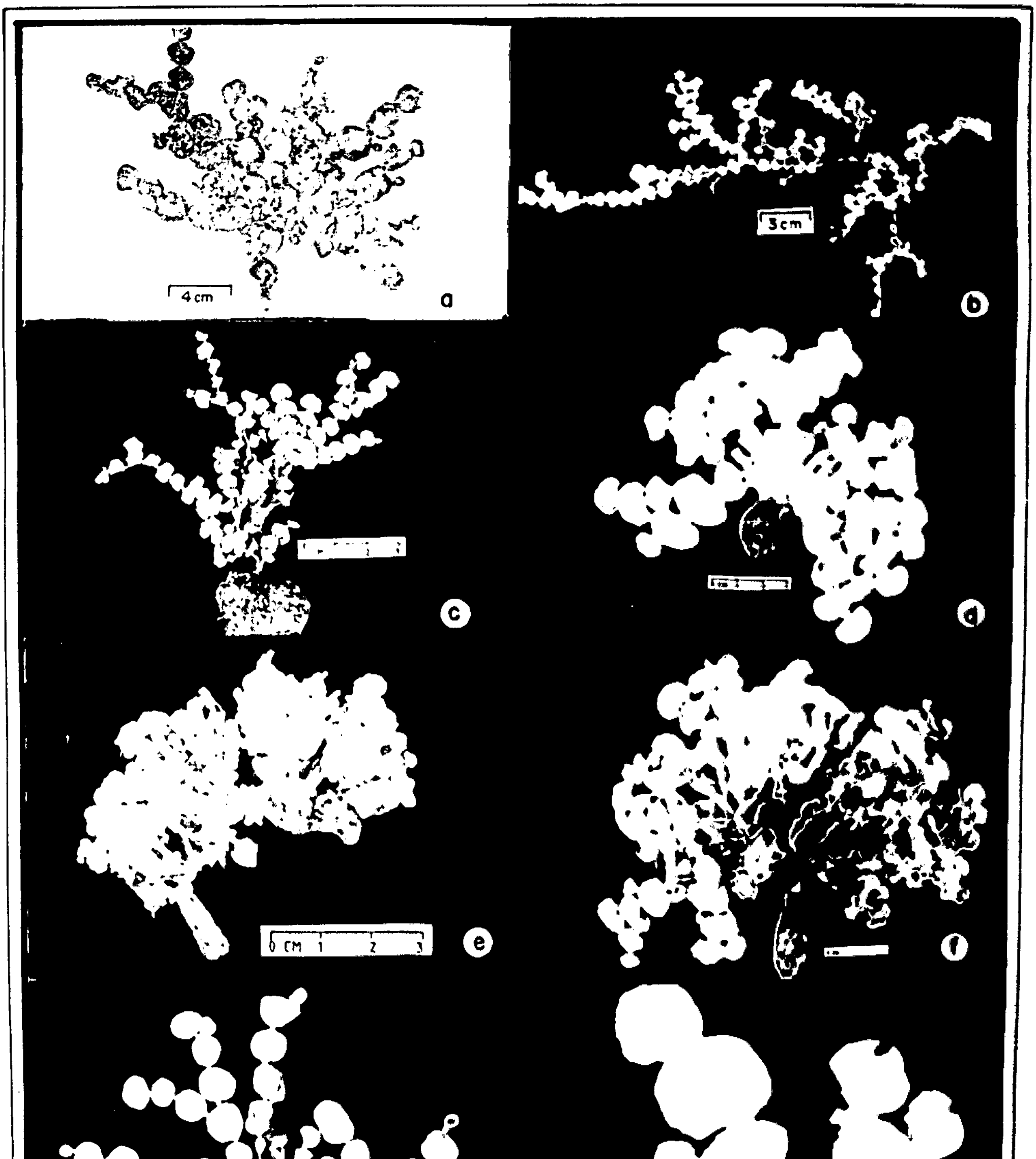


PLATE I

2. UDOTEA Lamouroux

Thalli are fan shaped and arise from a single holdfast. Filaments join laterally to form a pseudoparenchymatous structure. This alga mostly grows in the sandy or muddy substratum in the intertidal or subtidal region.

a) U. indica
A. & E.S. Gepp

Boergesen (1930), P. 161, Fig.5.

Habit-Habitat : This alga is collected from the upper littoral zone, growing in the muddy area. Thallus attains a height of about 5-8 cm. Stipe is 3-4 cm long and about 1-2 mm in width (Plate II f). Thallus is greenish and heavily calcified. Fronds are entire.

Anatomy : Lateral appendages occur on the filaments which are short, truncate and sometimes lobed having thickness of about 44 um. Papillae are lobed and on the periphery of the filaments (Fig. 10 a).

b) U. flabellum
(Ellis et Sol)

Tseng (1983), PL. 145, Fig. 3.

Habit-Habitat : Thallus is collected from the lowest intertidal region and from a depth of about 30 meters growing in the sandy area. Thallus is light green in colour, strongly zonate with a bulbous root mat and it is highly calcified. Stipe expands greatly to form a broad flabellum which is 10 cm in length and 15 cm in width. Stipe is 3 cm long and 4 mm in diameter irregularly splitting into several segments (Plate II e).

Anatomy : The frond is internally composed of corticating filaments which are 25-40 um in diameter, densely branched with numerous irregularly placed lateral appendages (Fig. 11 b). These appendages terminate into dactyline apices.

3. ACETABULARIA Lamouroux

Plants are small, delicate, attaining a height of about 0.5-10 cm terminating above in a disk. Calcification weak to heavy. Cells of the disk bear projections and form a ring called "Coronae". Cysts are produced in the rays.

A.calyculus, A. kilnerii, A.parvula from the Indian coast are described below.

a) A.calyculus
Quoy et Gaimard.

Boergesen (1930), P. 158-59

Habit-Habitat : Thalli are bright green in colour. Slightly calcified, growing on muddy rubble rocks or on shells in the lower intertidal zone, under calm conditions. Plants reach a height of about 3-4 cm (Plate II b). Stalk is rather rigid, calcified and with spindle shaped swelling bearing a whorl of hair scars (Fig. 11 a,b). Stipe ends into a lobed rhizome like thing. Ray disk is basin shaped, 4-6 mm in diameter with upward

FIG. 1Ø

Corticated filaments of *Udotea indica* Boergs and *U. flabellum* Ellis et Sol.

U. indica

a) Filament showing papillate appendages

U. flabellum

b) Filament showing dactyline appendages

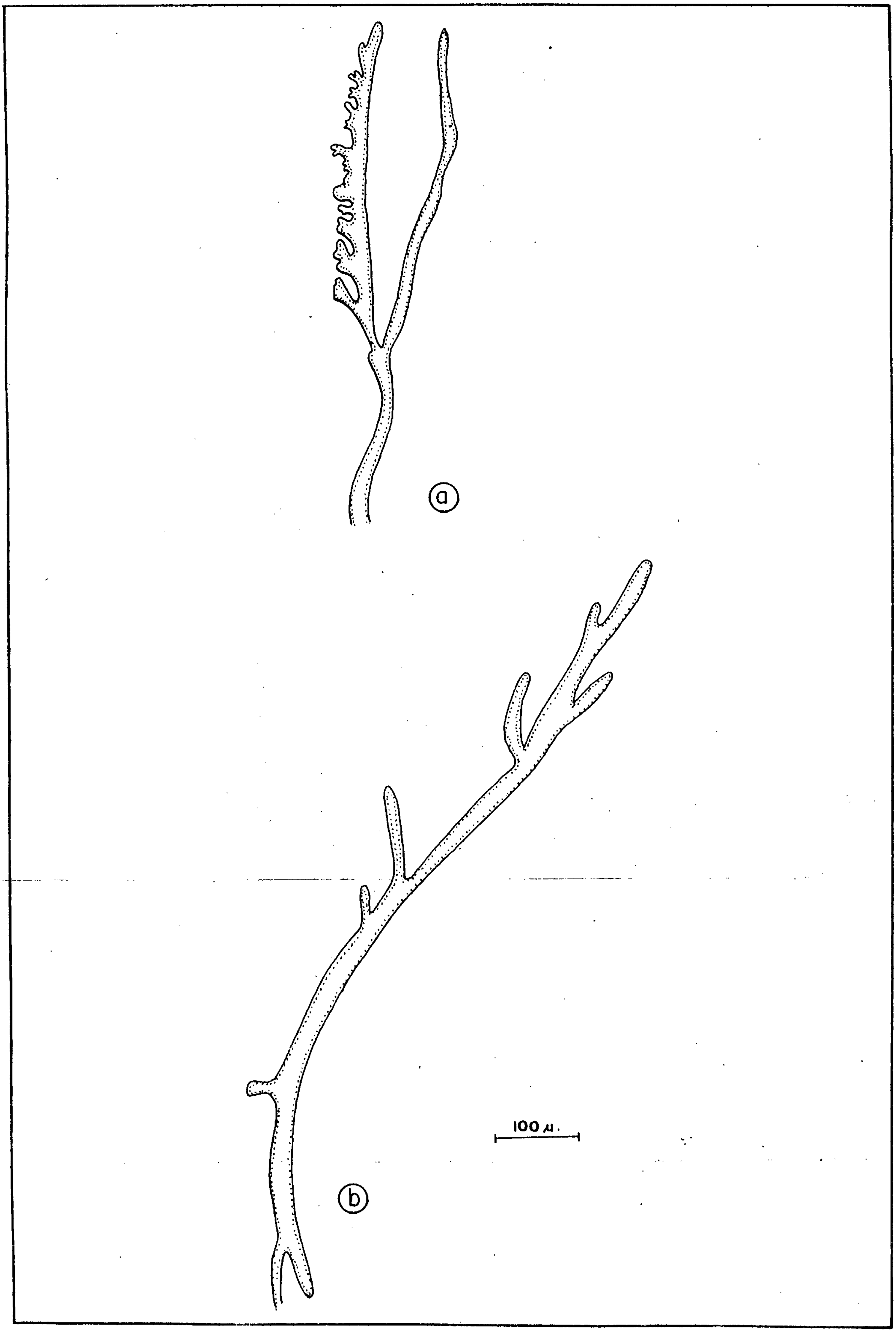


Fig. 10

curved rays, united in living conditions but separate on prolonged preservation and decalcification. Apices of the rays are rounded with depression in the central area (Fig. 11 a). Segments of the superior corona are cylindrical and bear 2-3 hair scars (Fig. 11 c). Corona inferior is irregular in outline (Fig. 11 c).

Reproduction : Cysts are 50-80 in number, round, each measuring 95-110 um in diameter (Fig. 11 d).

b) *A. kilneri*
J. Ag.

Valet (1969), Pl.36, Fig.3, Pl.37, Fig.1, Pl.43, Fig.1-5.

Habit-Habitat : Plants are about 3-5 cm in height, carrying a reproductive disk of 9-10 mm in diameter formed by 50-55 apiculate ray. (Plate II a). Calcification is run on the reproductive rays as strong lamellations joining the rays together. Rays are about 5-6 mm in length and about 642-646 um in breadth in the distal region, which shows a sharp point or blunt end and near the point of attachment, the rays are about 71 um in breadth (Fig. 11 e). Stipe of the plant is extremely long, smooth, terminating into a lobed rhizoidal system. Stipe is about 25 mm in length and about 0.5 mm in breadth. Both coronae are present. There are bilobed knobs of inferior corona measuring 176 um in length and about 48-80 um in breadth. In the knobs of superior corona 4-6 hair scars exist in an irregular radial manner (Fig. 11 f).

Reproduction : Cysts are spherical, free but close to one another, uncalcified, 100-150-200 in number and about 35-40 um in diameter (Fig. 11 g).

c) A. parvula
Solms. Laubach.

Egerod (1952) Fig. 23 i.

Habit-Habitat : Plants were found growing attached to the underside of calcareous rocks in the intertidal area and also in the deep waters on dead corals. Thalli are bright green in colour, solitary and slightly calcified, about 3-4 mm in height. Stipe is very short and ends into a branched rhizome (Fig. 11 h). The short stipe bears apical discs which is rounded, flat and small, about 3-4 mm in diameter. Number of rays varies from 12-16 and clavate in shape with rounded apices and measures about 0.8-1 mm long and 400-600 um wide (Fig. 11 h). Superior corona bears 4-6 hair scars (Fig. 11 i). Inferior corona is lacking.

Reproduction : Each fertile ray bears 30-60 cysts (Fig. 11 j) which are spherical and about 88-122 um in diameter. (Fig. 11 k).

FIG. 11

Details of _Acetabularia_ _calyculus_ Quoy et. Gaimard _A._ _kilneri_ J.Ag., _A._ _parvula_ Solms-Laubach.

_A._ _calyculus_ (a - d) :

a) Stalk with spindle shaped swelling

b) Hair scars on the stalk

c) Superior & inferior coronae

d) Cysts

_A._ _kilneri_ (e - g) :

e) Rays with pointed apex

f) Inferior corona & superior corona with trichocytes

g) Cysts

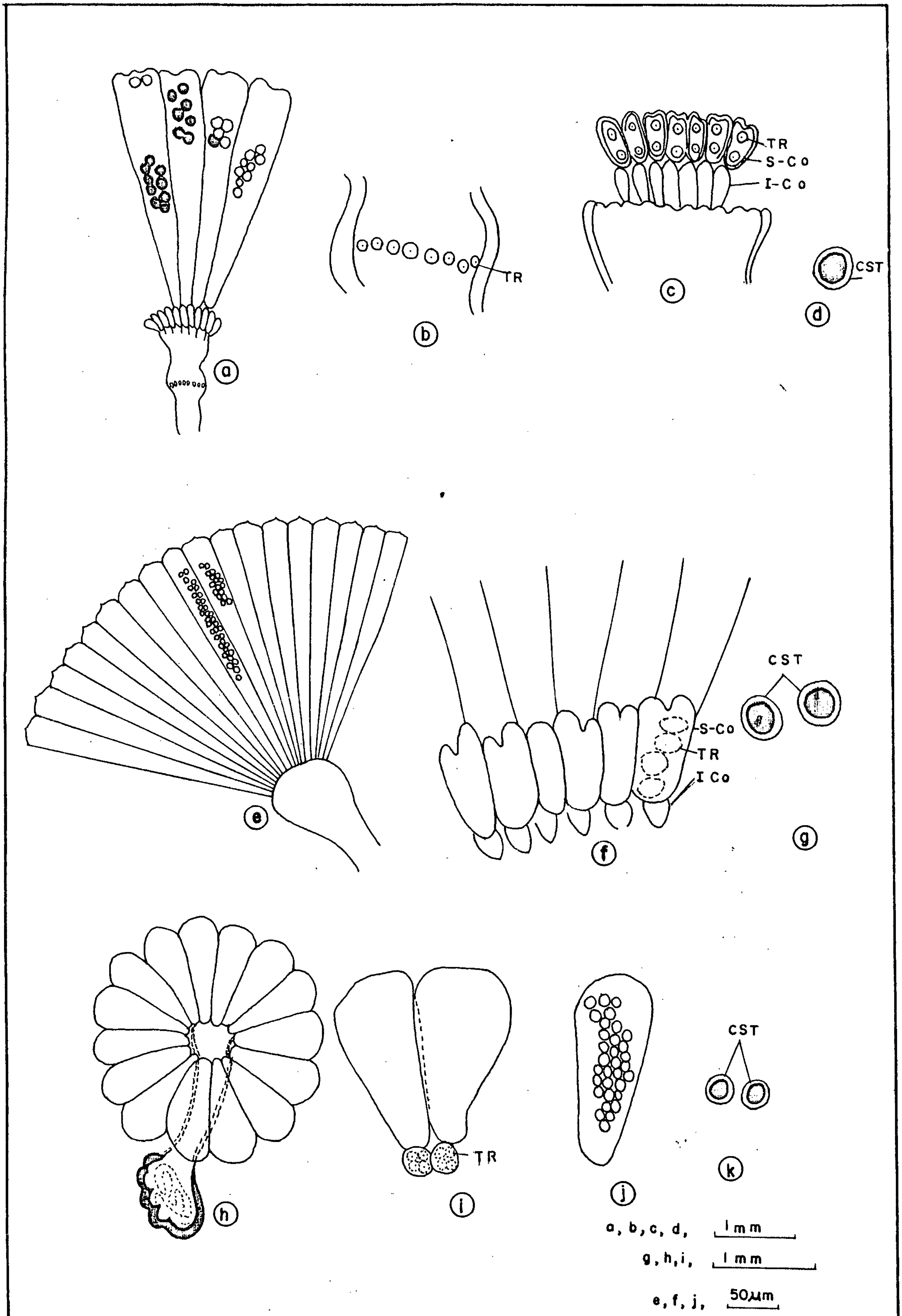
_A._ _parvula_ (h - k) :

h) habit

i) Rays and superior corona with trichocytes

j) Rays with cysts

k) Cysts


TR
S-Co
I-Co
TR
CST
a
b
c
d
CST
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TR
I Co
e
f
g
CST
TR
h
i
j
k
a, b, c, d, 1mm
g, h, i, 1mm
e, f, j, 50µm

Fig. II

4. NEOMERIS Lamouroux

Thallus is small, cylindrical about 2-3 cm in height. The central stem bears whorls of primary branches which divide into a stalked sporangium and secondary branches., Thallus is uncalcified around the central portion.

N. annulata and N. van-Bosseae are described below.

a) N.annulata Dickie

Egerod (1952), Pl.40, Fig.21 a-l and Fig. 22 a & c.

Habit-Habitat : Thalli are strongly calcified in the lower region and less in the apical region. Mostly grows on the calcareous rocks or on the dead corals in the intertidal region, also collected from the depth of about 38 meters. This alga was found to be associated with Acetabularia parvula. Plants are in clusters as well as solitary, attaining a height of about 1.5-2.5 cm (Plate II c). Tufts of deciduous hair arise from the apex. Primary branches are whorled, 200-300 um in size. Secondary branches arise in pairs producing deciduous hair at the apex. (Fig. 12 b). Inflated apex of secondary branches measures 110-150 um in diameter (Fig. 12 a).

Reproduction : Gametangia are obovoid, pedicillate, 230 um long and 110 um in diameter (Fig. 12 c). All these gametangia are cemented together in annular rows by a calcareous sheath.

N. van-Bosseae
Howe

Egerod (1952), Pl.41, Fig. 22 b.

Habit-Habitat : Thalli were found growing on the calcareous rocks and on dead corals. Thalli are light green in colour and strongly calcified in the lower region than the apical. Plants are in the cluster attaining a height of 1.5 - 2.5 cm. (Plate II d). The main axis gives rise to 28-40 whorls of laterals along the entire length. Primary branches are 460-580 um long. Secondary branches arise in pairs 340-400 um long (Fig. 12 e). The inflated apices of secondary branches are broad and conical, 180-220 um (Fig. 12 d). Secondary branches terminate into segmented, deciduous hair only at the apex, measuring about 1-1.5 mm in length (Fig. 12 e).

Reproduction : Gamentangia are free, pedicillate, 80-100 um broad (Fig. 12 e).

This alga is the first record for India.

FIG. 12

Details of Neomeris annulata Dickie and N. van-Bosseae Howe

N. annulata (a - c) :

a) Surface view

b) Longitudinal view of apex showing vegetative and reproductive branches

c) Mature branch enclosing gametangium

N. van-Bosseae (d - e) :

d) Surface view

e) Mature branch enclosing gametangium

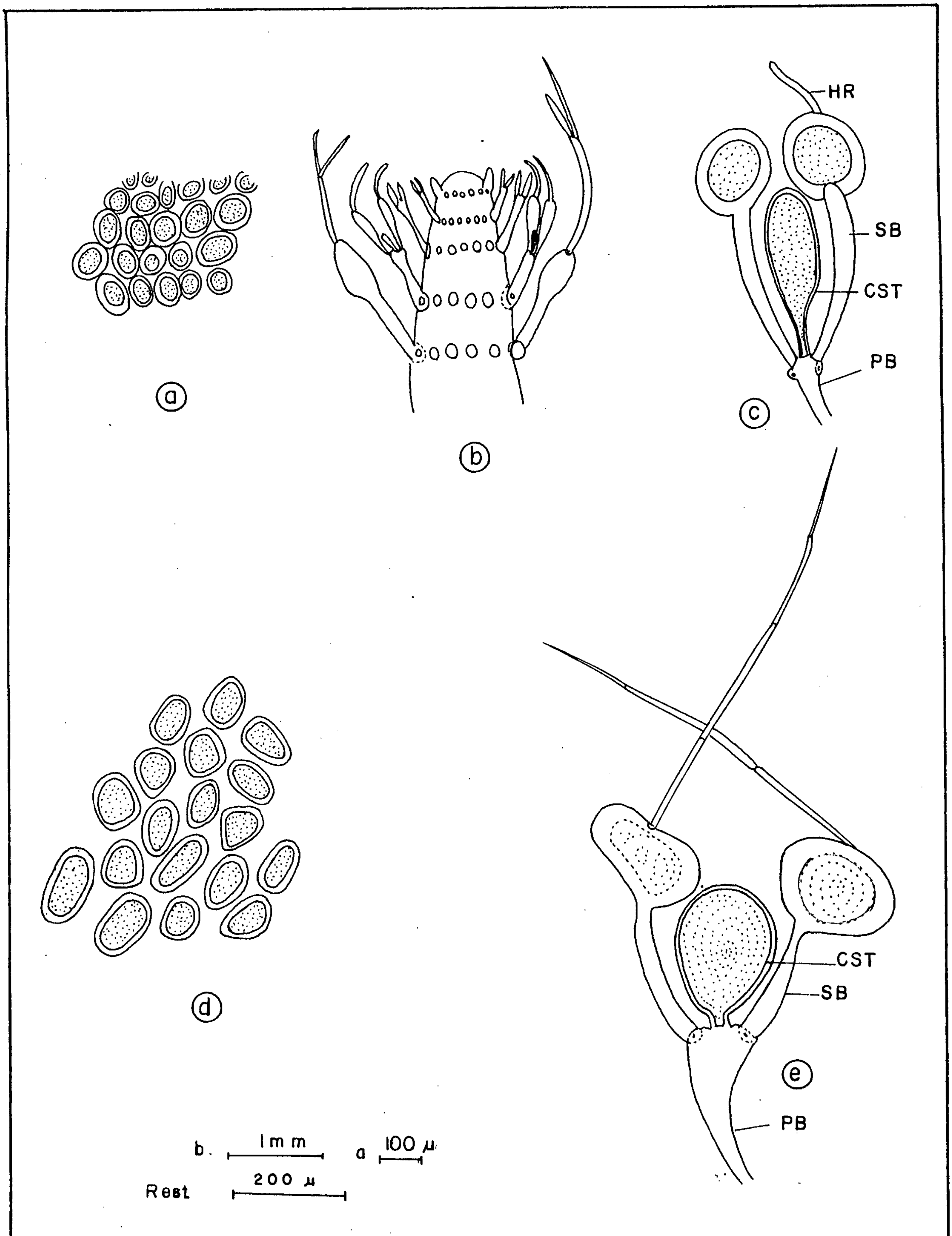

Fig. 12

PLATE II

a) Acetabularia kilneri
J. Ag.

b) A. calyculus
Quoit. et. Gaimard.

c) Neomeris annulata
Dickie

d) N. van-Bosseae
Howe

e) Udotea flabellum
Howe

f) U. indica
A. & E.S. Gepp

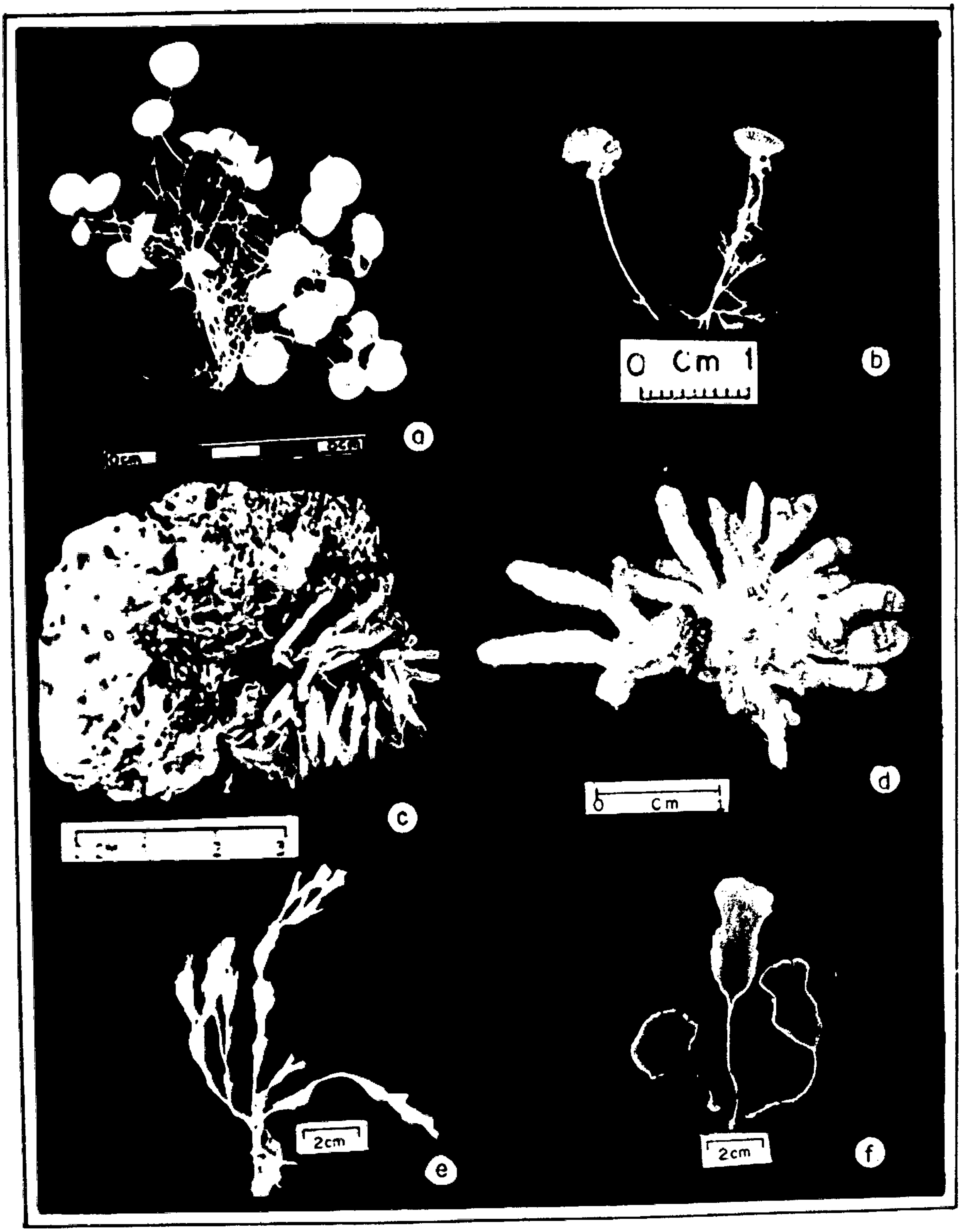

PLATE II

B) CALCIFIED BROWN ALGAE

1. PADINA
Adanson

Padina is the only calcified Phaeophycean form. Plants are of small to moderate size, fan shaped, growing from an inrolled margin and with a marginal row of apical cells. Attached to the substratum by an irregular holdfast. Rhizoids are developed from the lower portions of the blades. Blades are marked by concentric rows of hair and bear antheridia, oogonia, or tetrasporangia. These are sometimes in sori, in rows, or scattered. Surface is coated with lime.

a) P. gymnospora
(Kuetz) Vicker

Lewmanomont (1980), Plate I, Fig. 3, Plate II, Fig. 8

Habit-Habitat : Plants in tufts, 7-10 cm in height with short stipe and fibrous rhizoids, fronds are flabellate, membranous and concentrically zonate (Plate III a). Upper surface is more calcified than the lower one. Zonation at a distance of 3-4 mm. Fronds split into number of lobes.

Anatomy : Terminal part is composed of 3 layers of cells and 100-120 um in thickness (Fig. 13 b). Middle part is composed of 4 layers of cells, 150-200 um in thickness. Stipe and the lower parts composed of 3 layers of cells and 160 - 200 um in thickness. Rhizoids are produced from the lower parts of fronds (Fig. 13 a).

Reproduction : Every row of tetrasporangia with row of hair on either side leaving a broader sterile part between the rows of hair. (Fig. 13 c). Tetrasporangia are ovoid, 75-100 x 50-60 um in size. (Fig. 13 d). Spores are 90-100 um in diameter (Fig. 13 d).

P. pavonica (Linn.) Thivy

Lewmanomont (1980), Plate I, Fig. 4.

Habit-Habitat : Plants grow in varied habitats ranging from upper littoral to sublittoral zone. Also in polluted conditions. Fronds are mostly infested with Fosliella farinosa.

Plants 8-12 cm, brown in colour. Fronds are simple or dichotomously divided (Plate III c). Strongly encrusted with lime on the lower surface and less on the upper surface. Zonation at a distance of 2 mm.

Anatomy : Fronds composed of 3 layers of radially elongate cells. 150-200 um thick. Marginal portion is made up of two layers (Fig. 13 e). Stipe is 5-7 celled (Fig. 13 g).

Reproduction : Fertile bands are 1-2 mm broad. Sterile ones 3-5 mm broad. Sori on the ventral surface of the frond and on either side of each hair line with persistent indusium (Fig. 13 h). Spores are ovoid 100-120 x 70-100 um in diameter.

FIG. 13

Padina gymnospora (Kz.) vickers and *P. pavonica* (L.) Lamx.

P. gymnospora (a - d) :

a) T.S. of stipe showing rhizoids

b) T.S. of frond

c) T.S. through tetrasporangial sorus

d) Young tetrasporangia and tetraspore

P. pavonica (e - h) :

e) Part of lateral showing apical cell

f) T.S. of lower part of frond showing rhizoids

g) T.S. of stipe

h) T.S. of frond showing indusiate sporangia

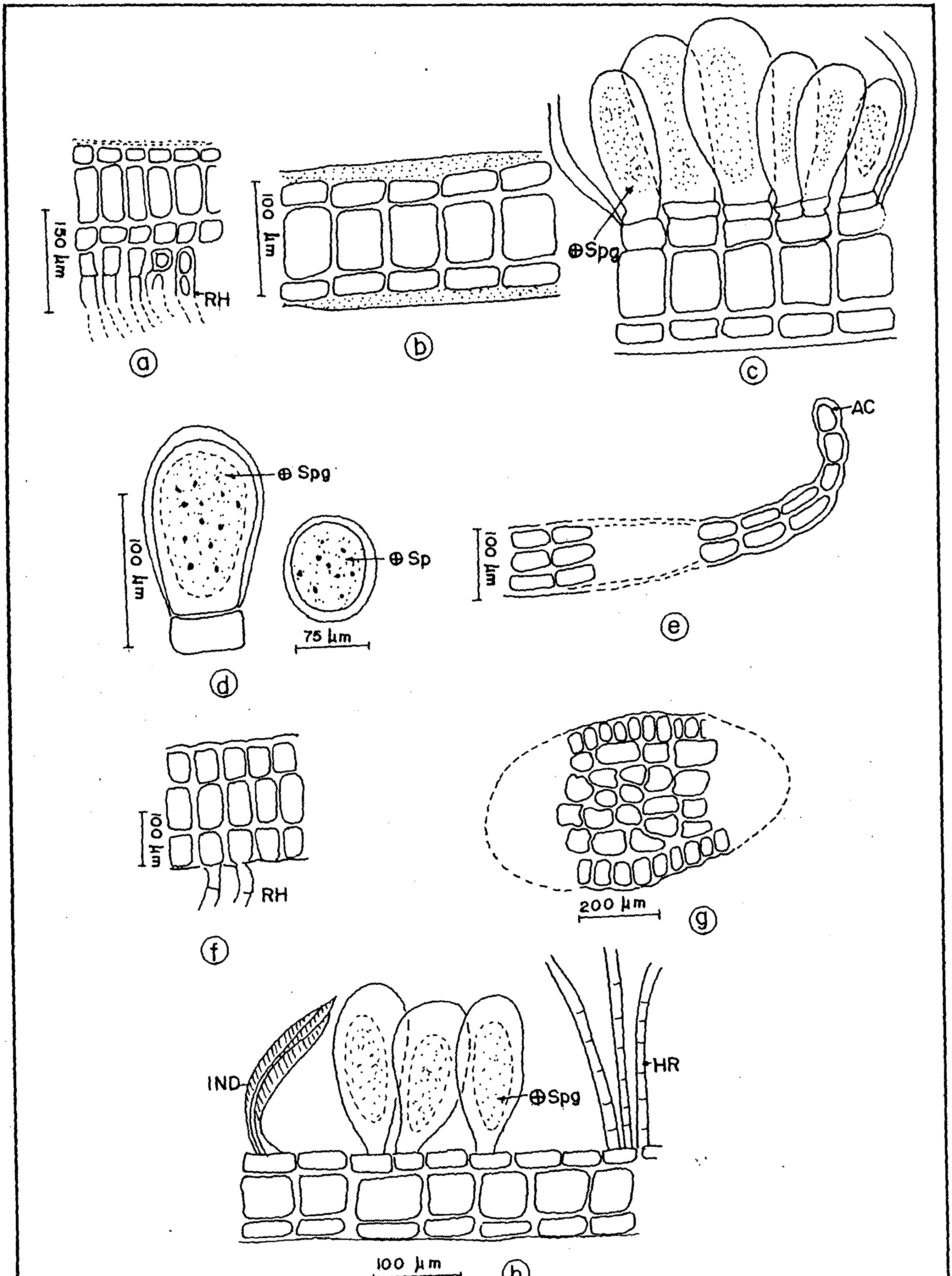

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Fig. 13

P. tenuis
Thivy.

Lewmanomont (1980), Plate II, Fig. 7

Habit-Habitat : This species grows in rock pools in the littoral zone, also in the lagoons. Plants dark brown in colour, 8-10 cm in height. From the basal rhizomatous portion, narrow stipe expands and bears fan shaped thallus. Fronds are mostly in tuft. (Plate III b). Upper surface is strongly calcified.

Anatomy : Near the apical region, frond is composed of two layers of cells. Stipe is made up of 3 layers of cells (Fig. 14 b) and produces rhizoids in the lower portion (Fig. 14 c). Lower part of the lobe is 4 celled (Fig. 14 d).

Reproduction : Fertile and sterile zones alternate. Sterile zone is 2-3 mm broad, fertile zone is 0.5 mm broad. Tetrasporangia are stalked 70 - 150 x 50 - 100 um (Fig. 14 e,g). Tetraspores are round and 90 x 100 um in size (Fig. 14 f).

FIG. 14

Padina tenuis Bory (a - g) :

a) Part of lateral showing apical cell

b) T.S. of frond

c) T.S. of stipe

d) T.S. of the lower part of frond

e) Young tetrasporangium

f) Spores

g) T.S. through tetrasporangial sori

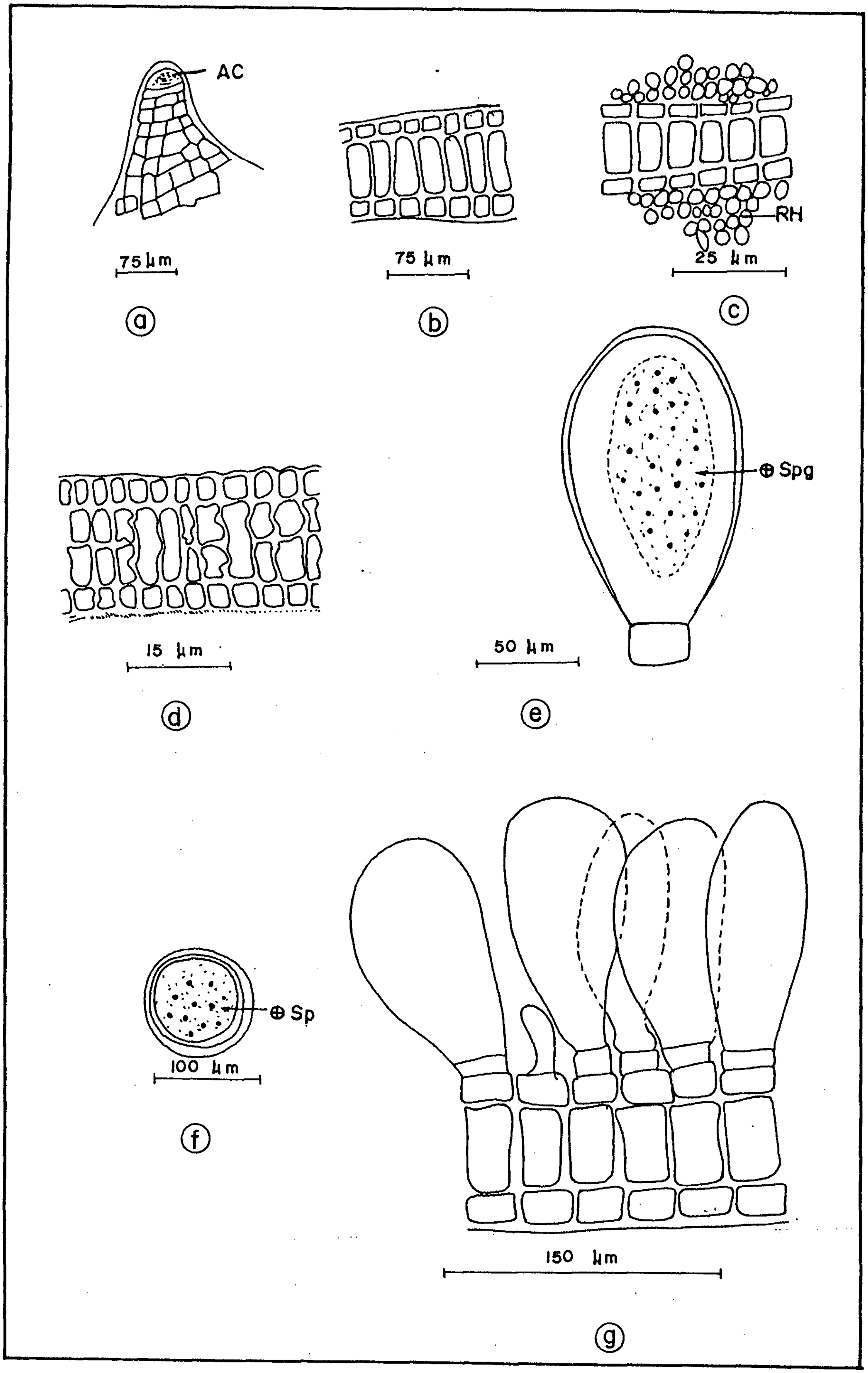


Fig. 14

PLATE III

a) *Padina gymnospora* (Kuetz) Vicker.

b) *P. tenuis* Thivy ex. Taylor

c) *P. pavonica* (L.) Thivy ex. Taylor

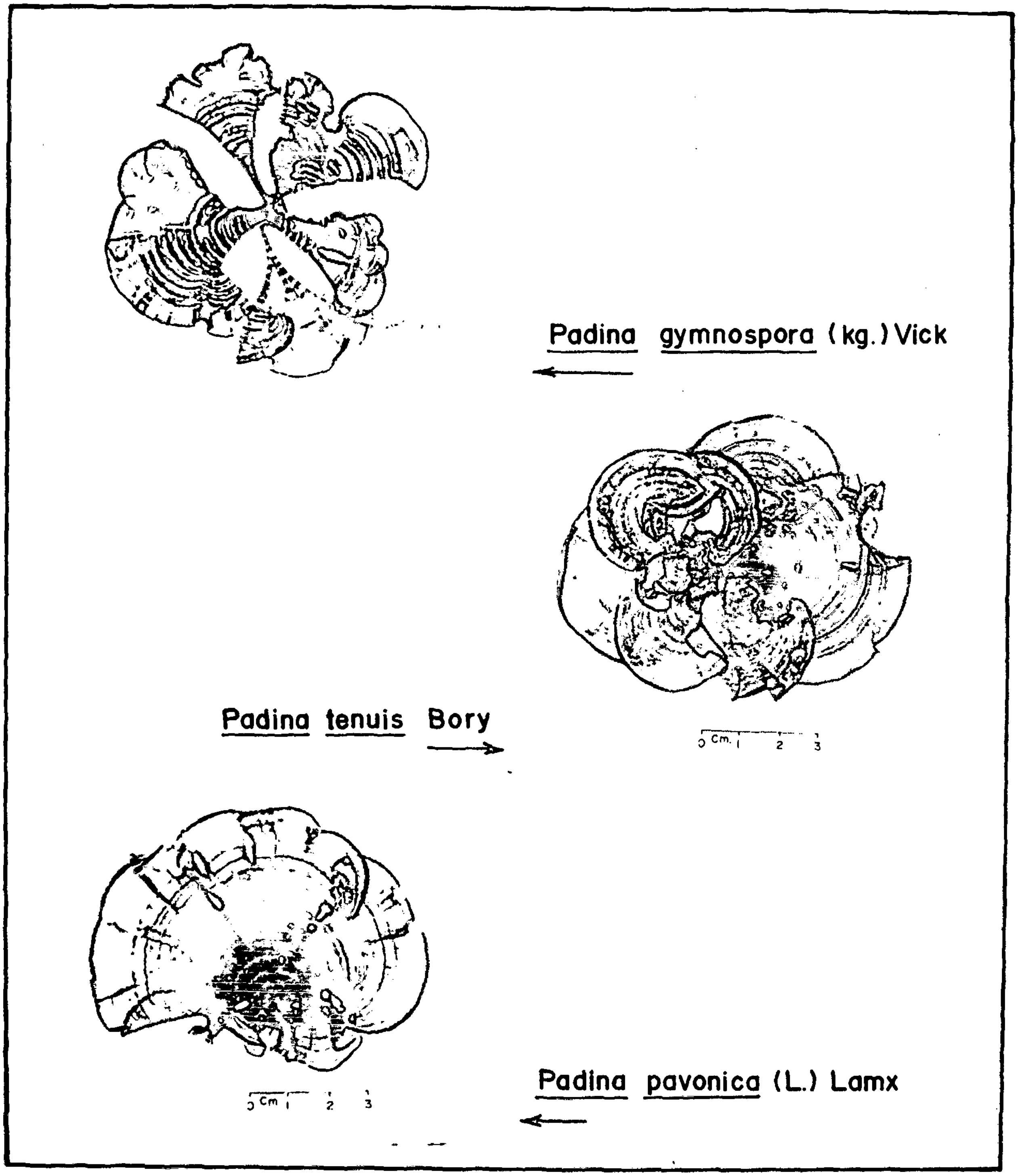

Padina gymnospora (kg.) Vick
Padina tenuis Bory
0 Cm. 1 2 3
Padina pavonica (L.) Lamx
0 Cm 1 2 3

PLATE III

C) CALCIFIED RED ALGAE

1) ACTINOTRICHIA
Decaisne

Actinotrichia is the smallest among the member of family Chaetangiaceae. This moderately calcified cartilagenous alga resembles Galaxaura but can be distinguished by the presence of persistent assimilatory filaments. Male and female organs on different individuals.

Actinotrichia fragilis is the only species of this genus and is described below.

Actinotrichia fragilis
(Forssk.) Boergs

Kylin (1956), P. 120, Fig. 74A.

Habit-Habitat : This alga grows in the lower midlittoral zone, on the calcareous rocks. It is bright red in colour and grows upto 3-5 cm. Attached to the substratum by means of a basal disk. Additional rhizoids are produced when it comes in contact with any substratum (Fig. 15 b). Axis is solid, cartilagenous, calcified, cylindrical, slender, terete and branched dichotomously and trichotomously producing 10-12 forkings (Plate IV a,b). Assimilatory filaments arise from the surface and occur in definite whorls which are persistent throughout (Fig. 15 a).

Anatomy : Thallus is three layered. Epidermis is single layered made up of subglobose cells. Assimilatory filaments arise from these epidermal cells. Epidermal cells measure 22 x 11 um in dimension and appear hexagonal in shape containing a single stellate chromatophore (Fig. 15, d).

Pseudoparenchymatous cortex is two layered. The outermost layer of the cortex is made up of hexagonal cells measuring about 17 - 22 um x 14 - 22 um. Cells of the second layer are larger and irregularly hexagonal and measure 22-29 um x 16-22 um (Fig. 15 f).

Assimilatory filaments arise from the epidermal cells which measure about 400 um in diameter. These cells are made up of elongated cells. Each cell measures about 22-33 um x 8-11 um broad and shows the presence of plate like chromatophores (Fig. 15 e).

Calcification takes place in all the parts excepting the central part of medulla. It is heavier in the inner parts as compared to the outer parts. (Fig. 15 c).

<u>Reproduction</u> :

Asexual : It reproduces asexually by forming tetraspores. Tetraspores are borne singly and terminally on assimilatory filaments (Plate IV c,d, Fig. 15 j). Tetrasporangia divide cruciately to produce four tetraspores (Fig. 15 j). Assimilatory filaments bearing tetrasporangia are 4 to 12 celled (Plate IV c). Sometimes assimilatory filaments bearing tetrasporangia are branched, each lateral terminating into tetrasporangium (Plate IV, d).

Sexual : Male and female plants are different. Male plants were not observed in collection.

Cystocarpic plants are smaller and branched densely compared to the tetrasporic plants (Plate IV b).

Cystocarps are globular, ostiolate, embedded in the medulla and formed on the upper part of the thallus (Plate IV,e). Carpogonial branch originates from the upper cell of young assimilatory filaments. Carpogonial branch is 3 celled, comprising a single terminal carpogonium; median hypogynous cell and basal pericarpic initial (Plate IV, f Fig. 15 h). Carpogonium is conical in shape and about 10 um long with a terminal trichogyne 25 um long. Hypogynous cell is 15 um long and 9 um in width which undergoes vertical divisions before fertilization to produce four hypogynous cells. (Plate V, Fig. 15 h). Pericarpic initial produces long filaments from the lateral side which surround the carpogonial branch giving a well defined fructification (Plate IV,h). Gonimoblast initials are given out from the hypogynous cell (Fig. 15 i). The gonimoblast filaments form a dense compactly arranged mass which is surrounded by pericarp (Plate IV,g).

FIG. 15

Actinotrichia fragilis Forssk. (a - j)

a) Filament showing the whorls of persistent hair

b) Production of additional rhizoids

c) T.S. showing calcification in all the parts excluding central part of medulla

d) Surface view with stellate chloroplast

e) Assimilatory filaments with plate like chromatophores

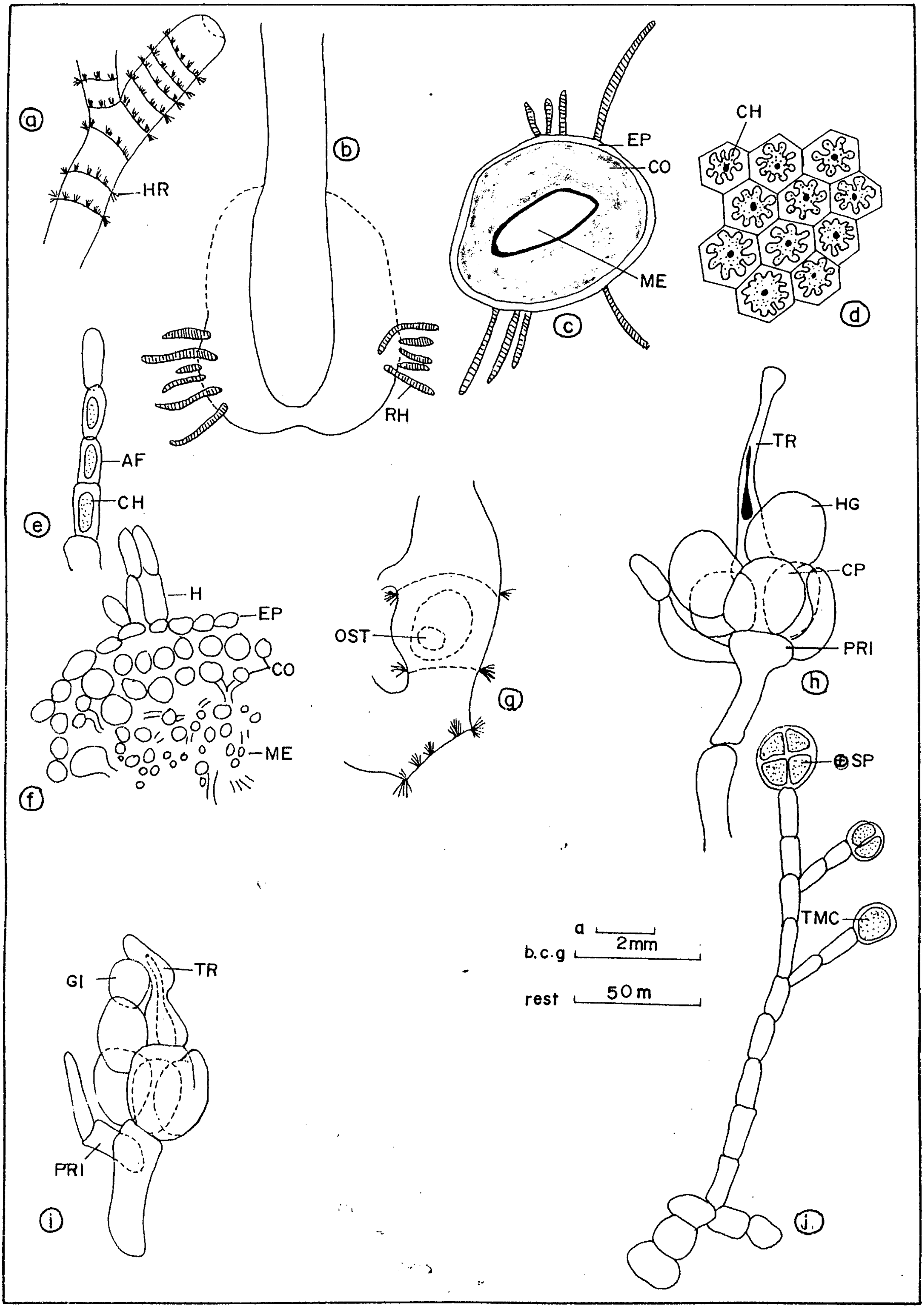
f) T.S. showing pseudoparenchymatous cortex

g) Ostiolate cystocarp

h) Carpogonial branch

i) Carpogonial branch showing formation of gonimoblast initials

j) Assimilatory filaments with tetraspores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a 2mm
b.c.g
rest 50m
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TR
PRI
i
j

Fig. 15

PLATE IV

<u>Actinotrichia</u> <u>fragilis</u> (a-g)
Forssk.

a) Tetrasporic plant

b) Cystocarpic plant

c) Assimilatory filament bearing terminal tetrasporangium

d) Branched assimilatory filament each bearing terminal tetrasporangium

e) Ostiolate cystocarp

f) Carpogonial branch

g) Hypogynous cells giving rise to gonimoblast filaments

h) Mature fruiting body

<u>Galaxaura</u> <u>oblongata</u>
(Ell. et. Sol.) Lam.

i) Fruiting body

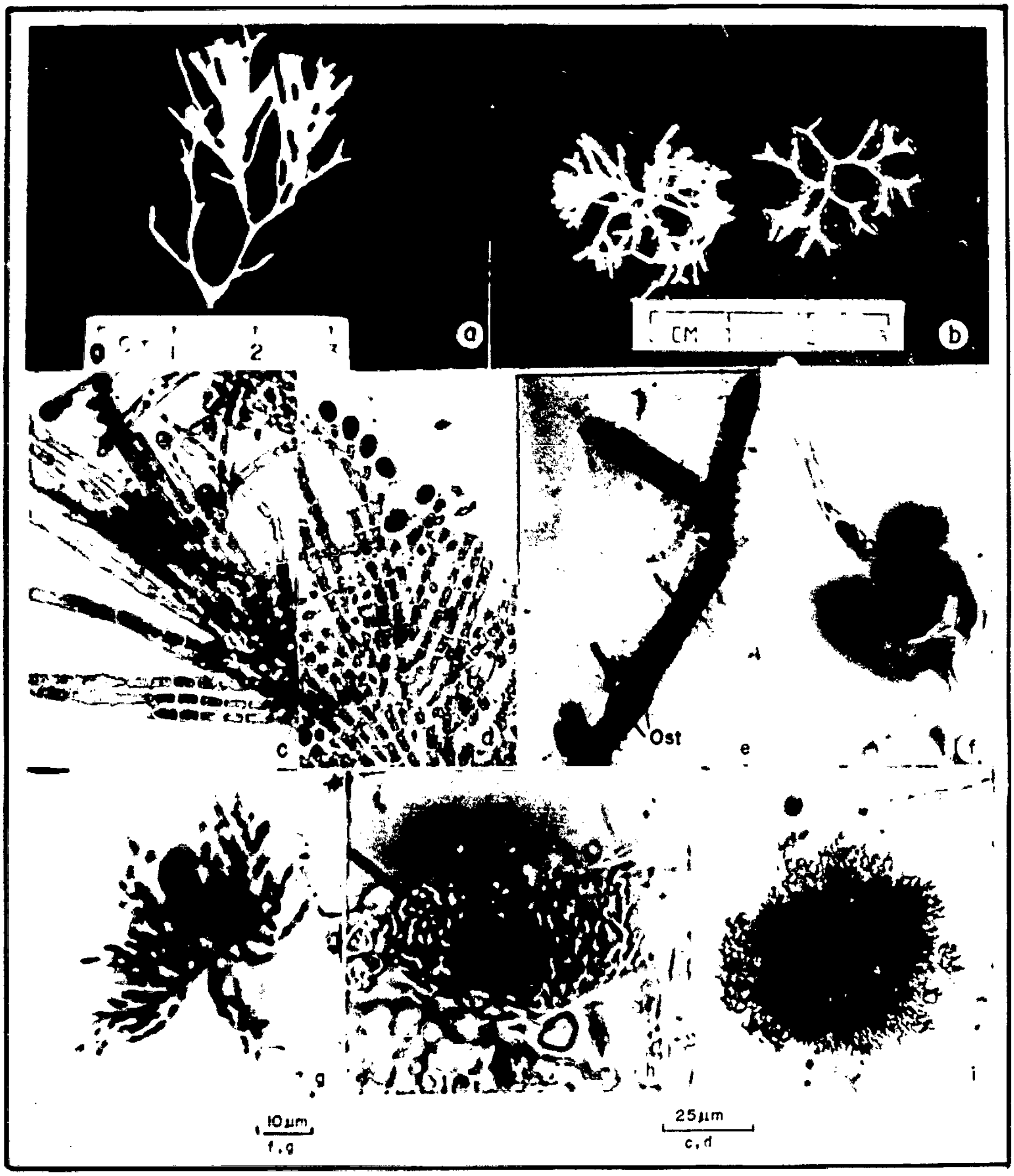

PLATE IV

2) GALAXAURA
Lamouroux

Plants are encrusted with lime. Branching is irregularly dichotomous. Anatomically composed of a loose medulla of slender, colourless, branched filaments which give rise to more compact cortex. Assimilatory filaments are elongated and give hairy appearance to branches. Antheridia and carpogonia on separate plants. Cystocarps are immersed and discharge through pore. Morphological alternation of generation present.

Extent of calcification in this genus varies from species to species.

G. lapidescens, G.lenta, G.marginata, G.oblongata, G.rugosa occur along the Indian coast.

a) G.lapidescens
(Ellis et. Sol.) Lamour.

Papenfuss et. al. (1982), P. 407, Fig. 4, 5, 22, 23, 34, 44.

Habit-Habitat : Grows in the lower mid-littoral zone on calcareous rocks.

Thallus attains a length of about 10 cm, attached to the substratum by means of discoidal holdfast. Thallus is blackish red in colour and becomes yellow upon preservation. Fronds are cylindrical terete and about 2-2.5 mm in thickness. This species can be easily identified as the thallus is clad with a dense felt of assimilatory filaments. (Plate V a).

Anatomy : An ill-defined cortex surrounds the central medulla which is composed of dichotomously branched medullary filaments. Cells of medullary filaments have a length of about 330 um and width of about 12 um (Fig. 16,c).

Two kinds of assimilatory filaments i.e. long and short are observed in this species (Fig.16 b). The short assimilatory filaments are 2-4 celled while long assimilatory filaments are many celled. Each assimilatory filament arises from a characteristic swollen basal cell (Fig. 16 c). The basal cell is globose and 33-40 um in diameter. The medullary filaments terminate into a supporting cell which is subcylindrical in shape having a length of about 44 um and width of about 22 um. Basal cell is formed from a supporting cell. (Fig. 16 c).

Long filaments are about 25-30 celled and vary in length according to the number of cells per filament. The length of the filaments varies from 160-800 um. The cells of assimilatory filaments are elongate and cylindrical measuring about 20-48 x 10-14 um. The chromatophore is plate like. Occassionally long filaments show dichotomy (Fig. 16,d).

Short filaments vary in length from 60-80 um. In case of 3 celled filaments, the innermost cell is subspherical, the middle cell is barrel shaped and the outermost is globose.

Calcification : Calcification is very intense in the peripheral parts and sparsely seen in the medullary region (Fig. 16 a).

b) G.lenta
Kjellman

Papenfuss et. al. (1982), P. 410, Fig. 6, 35

Habit-Habitat : Thalli grow on the calcareous substratum in the lower midlittoral and subtidal zone. Thalli grow upto a height of about 10-12 cm, attached to the substratum with the help of discoidal holdfast. The main axis branches dichotomously. Main axis is terete cylindrical and about 2-2.5 mm in diameter. Thallus is articulated at irregular intervals. Length of the segments varies from 3-20 mm (Plate V,b).

Anatomy : Central medulla is surrounded by a cortex. The cortex is about 110 um in thickness. Medulla is composed of loose filaments which are branched sparingly and subdichotomously. Cells in the medullary filaments are cylindrical and measure about 78-360 um in length and 8-28 um in width. (Fig. 16 e). Cortex is 3 layered. The inner cells are bigger in size globose and measure about 36-40 um in diameter and form a continuous cortical layer. Cells of this layer give rise to one or more "stalk cells" which are squarish in shape and measure about 40 x 32 um (Fig. 16 f). Cells of the middle layer are the smallest compared to the cells of other two layers. The stalk cells bear one assimilatory cell in the beginning (Fig. 16 f) but soon it produces a lateral outgrowth. Occasionally, it gives rise to a pair of assimilatory cells. In each assimilatory cell, there is a single prominent chromatophore which is parietal in position and 'medussa' like (Fig. 16 e).

Calcification : Calcification takes place around the basal region of medullary filaments and restricted towards the peripheral region. The medulla lacks the deposition.

c) *G. marginata* (Ellis et. Sol.) Lamour.

Papenfuss *et*. *al*. (1982), P. 410, Fig. 7, 9, 24, 36, 37.

Habit-Habitat : Grows on calcareous rocks in the lower mid-littoral and sub-littoral zone. Fronds are greyish in colour lightly calcified and attain a height of about 5-6 cm. From the basal disk several main axes arise. Each one divides dichotomously giving rise to about 6-8 forkings. Basal portion of the axis is terete but flattens in the upper part (Plate V c). Thallus is stipitate as the upper portions possess short stipes. Branching is dichotomous. Branches are about 2 mm broad. Thallus is constricted and the annulations on the surface are seen.

Anatomy : Central broad medulla which is composed of loose, dichotomously branched filaments about 12-16 um broad. Medulla is surrounded by a pseudoparenchymatous cortex (Fig. 17 d). The cells of medullary filaments are elongated and measure about 160 um x 16 um in size. The cortex without papillae is about 160 um in width and about 190 um in places where epidermal cells have developed papillae (Fig. 17 c).

Thallus is three layered. The outermost epidermal cells measure about 32-48 x 32 um which are irregularly pentagonal in shape and smaller compared to the cortical cells (Fig. 17 c).

FIG. 16

<u>Galaxaura lapidescens</u> (Ellis et. Sol) Lam. and <u>Galaxaura lenta</u> Kjellman

<u>G. lapidescens</u> (a - d)

a) T.S. showing calcification in the cortical region and also in the medullary region.

b) Short and long assimilatory filaments with plate like chloroplast

c) Short assimilatory filament with swollen basal cells.

d) Dichotomously branched long assimilatory filament

<u>G. lenta</u> (e - g)

e) Cortex

f) Stalk cell

g) Calcification in the peripheral region

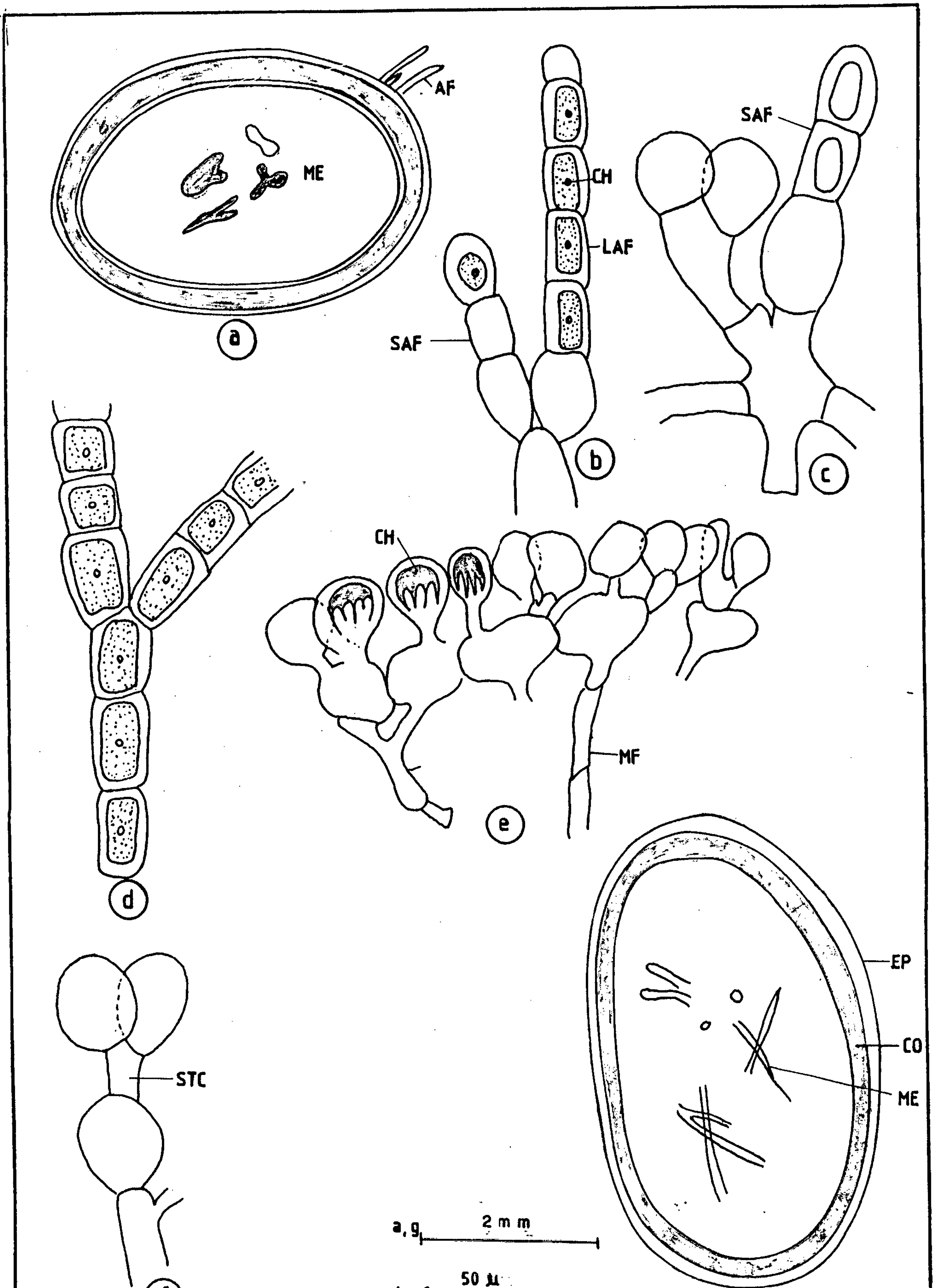

Fig. 16

Epidermal cells show the presence of characteristic stellate chloroplasts (Fig. 17 b). The cells of the first cortical layer are 32-48 um in length and about 32 um in width. The cells of the innermost layer are the largest and measure about 48-64 um in breadth. Apical papillae arise in a single row from the epidermal cells. These are smooth and mucronate. The apical papillae arise only from the margin of the thallus.

Calcification : Thallus is lightly calcified. Calcification takes place only in the epidermal zone (Fig. 17 a). The papillate cells, cortex and medulla remain uncalcified.

d) G. oblongata (Ellis et. Sol.) Lamour.

Papenfuss et. al. (1982), Fig. 10, 13, 25, 26, 38.

Habit-Habitat : Collected from the intertidal and subtidal areas. Thalli are slender, 10-12 cm tall. Branching is profuse and dichotomous. Branches are 1-3 mm in diameter, smooth and heavily calcified, bright pink in colour, become white upon preservation. Segments are narrower at the basal end (Plate V e).

Anatomy : Epidermal layer is composed of sub-globose cells, 16 um in diameter. In surface view they appear mainly pentagonal with plate like chloroplast (Fig. 17 f). Medulla consists of dichotomously branched medullary filaments, 6-10 um in diameter terminating into 2-3 sub-globose inner cortical cells (Fig. 17 g). Inner cortical cells are 20-40 um in diameter. Each in turn bears 2 or 3 subglobose cortical cells, 20-30 um in diameter. Upon decalcification, cluster of filaments separate. Pit connection is visible (Fig. 17 g).

Cystocarp : A mature cystocarp is spherical and 260 um in diameter and sunk in the cortical region (Plate IV,i).

Calcification : It is localized upto the cortical zone and peripheral part of medulla (Fig. 17 e).

e) G. rugosa
(Ellis et. Sol.) Lamour.

Papenfuss et. al. (1982), P. 410, Fig. 10, 13, 25, 26, 38.

Habit-Habitat : It was collected from the intertidal area and also from the depth of about 18-35 meters. Thallus is blackish red, bushy, attaining a height of about 8-10 cm. Branching is regularly dichotomous. The main axis is terete, 1-1.5 mm in diameter. Lower parts are rugose. Apical region shows annulations (Plate V d).

Anatomy : Anatomically it shows single layered epidermis and two layered cortex which surrounds the mass of medullary filaments (Fig. 17 j).

Epidermis is single layered, made up of more or less angular cells and measure about 22-26 um in diameter. In surface view, these cells look hexagonal with stellate chloroplast (Fig.17 i). Assimilatory filaments arise from these epidermal cells which measure about 22-33 x 15-19 um.

Cortex is pseudoparenchymatous. The cells of the 1st cortical layer measure about 22-33 um in diameter. Cells of the second cortical layer measure about 36-55 um in diameter and often show fusion with the adjacent cells forming a 'lobed fusion cell' (Fig. 17 k). This lobed fusion cell measures about 70-80 um in width and 120-150 um in length. Medulla consists of entangled mass of unpigmented filaments having a diameter of 8-18 um.

Calcification : Calcification is localized upto cortical region (Fig. 17 h).

FIG. 17

Galaxaura marginata, (Ell. et. Sol.) Lam.,

G. oblongata (Ell. et. Sol.) Lam.

G. rugosa (Ell. et. Sol.) Lam.

G. marginata (a - d)

a) T.S. showing calcification in the epidermal region

b) Surface view showing stellate chloroplast

c) Epidermis with apical papillae

d) Cortex

G. oblongata (e - g and j)

e) T.S. showing calcification in the cortical region

f) Surface view with plate like chloroplast

g) Cortex with loose cluster of filaments

j) Cortex showing pit connection

G. rugosa (h, i and k)

h) T.S. showing calcification in the cortical region

i) Surface view with stellate chloroplast

k) Lobed-fusion cell in the second cortical layer

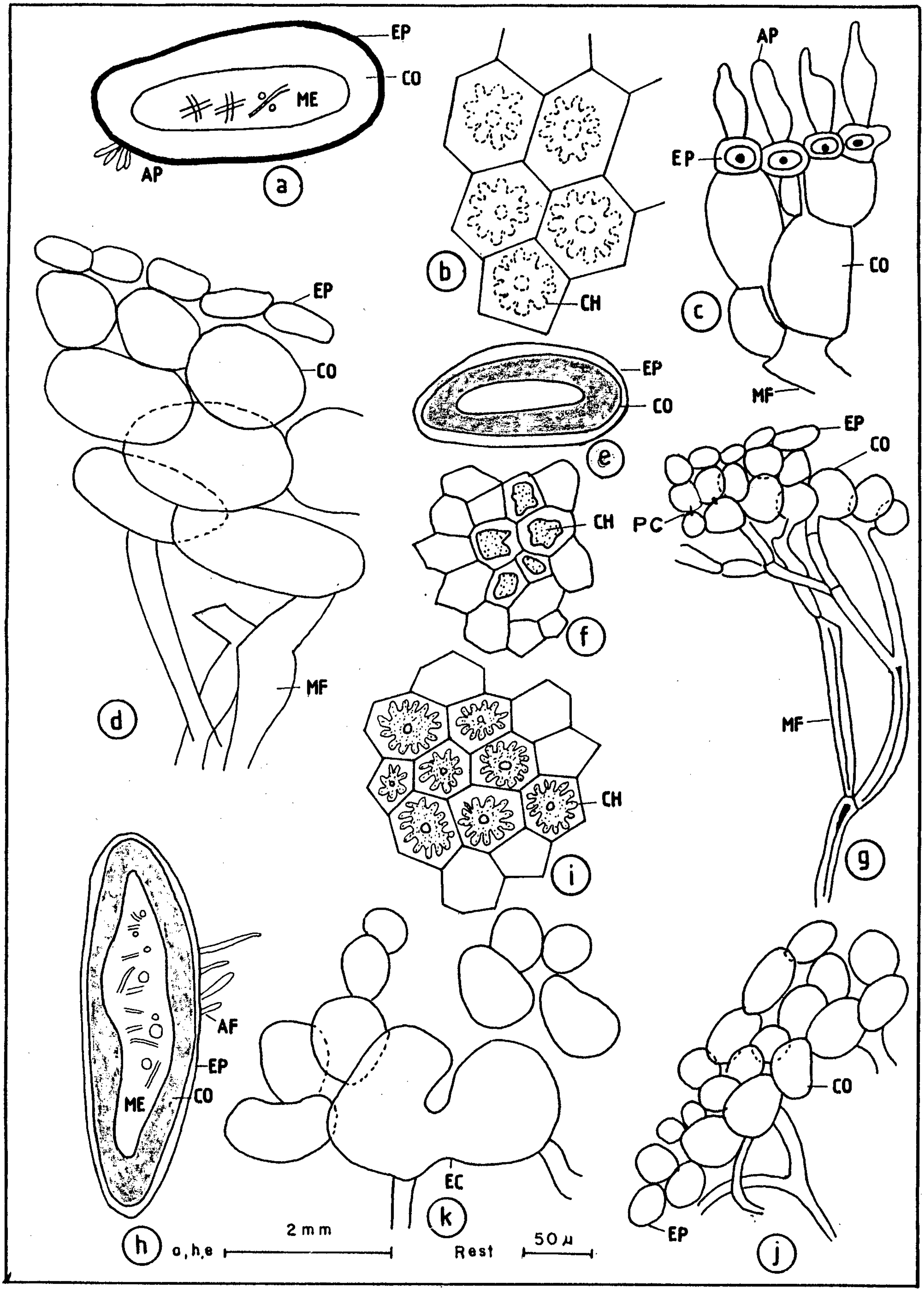
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Fig. 17

3. LIAGORA
Lamouroux

Liagora is a widely distributed tropical genus. Species of Liagora show variability in size, habit and amount of calcification. Lateral proliferations are found in some species.

Structurally, thallus is multiaxial with a central medullary strand of vertically running branched filament while surrounding cortex is made up of the lateral branches of the medullary filaments.

Species are monoecious or dioecious. Antheridia are either produced in loose or compact clusters. Carpogonial branches are laterally produced from the basal region of assimilatory filament. L. ceranoides, L.doridis, L. indica and L. visakhapatnamensis are described below.

a) L. ceranoides
Lamouroux

Desikachary and Balakrishnan, (1957), P. 460, Figs. 15-27.

Habit-Habitat : Thalli grow on calcareous rocks in the lower midlittoral zone. Thallus is highly mucilagenous and grows upto 4-6 cm in height. It is pale greenish yellow in colour. Branching is dichotomous. Proliferations are absent or very rarely present (Plate V f).

Anatomy : Cells of the medullary filaments are elongate and measure about 188-210 x 8 - 12 um in size. Assimilatory filament is 6-8 celled and cells measure about 33-44 x 11-15 um; 25-30 x 5-11 um; 15-18 x 8-11 um, 7-9 x 5-9 um and 5 x 4 um respectively (Fig. 18 a).

Reproduction : Plants are dioecious. Antheridial plants were not found in collection.

Carpogonial branches are lateral and four celled (Fig. 18 b). Carpogonium is conical (8 x 3.5 um). Hypogynous cells measure about 6-8 x 5-7 um. Trichogyne is not very long (30 - 35 um) and slightly swollen at the apex.

Fertilized carpogonium divides transversely. Upper cell takes part in the formation of gonimoblast filaments. These are small globular and 2-2.5 um in diameter (Fig. 18 c).

Involucral filaments are seen even before fertilization, but they do not envelope the gonimoblast filaments (Fig. 18 c).

b) L. doridis
Zeh

Krishnamurthy and Sundararajan (1987), P. 72, Fig. I, 4-14.

Habit-Habitat : Thalli grow on calcareous rocks in the sublittoral zone by a small circular disk. Thallus is light purple in colour and turns white upon preservation. Calcification is heavy. Thallus is about 6-8 cm in height and dichotomously branched. Proliferations are completely absent (Plate V h).

Anatomy : Cells of medullary filaments are elongate and 250 325 x 18-30 um in size. Assimilatory filament is about 264 um x 6-8 times furcated (Fig. 18 e). Cells of the assimilatory filaments become gradually smaller and measure 44-66 x 9-13 um; 25-30 x 7-11 um 15-13 x 6-8 um and 5-8 um respectively.

Reproduction : L. doridis is dioecious species. Only female plants were observed in our collection.

Carpogonial branch is terminal and given out from the middle portion of assimilatory filament and measures about 120 - 135 um. It is curved and 3-6 celled. Mostly it is five celled (Fig. 18 f, g).

Carpogonium is somewhat triangular and 12-17 x 5-10 um in size. Hypogynous cells measure about 12-17 x 5-10 um. Trichogyne is long and measures 98-110 um in length (Fig. 18 h) and persists even after fertilization.

Fertilized carpogonium divides transversely (sometimes more than once) (Fig. 18 h). Gonimoblast initials are formed from the upper cell which divide dichotomously (Fig. 18 i) to form a dense structure i.e. cystocarp.

c) L. indica Sundararajan

Sundararajan (1984), P. 78-86, Fig.82 - 105, PL. III g, i.

Habit-Habitat : Thallus is attached to the calcareous substratum by means of basal circular disk. Thallus is light green in colour and grows upto a height of 4-5 cm. Calcification is heavy. Branching is mostly dichotomous, very rarely trichotomous. Main axis is 1 mm thick. Proliferations are completely absent (Plate V g).

FIG. 18

Liagora ceranoides Lamour., *L. doridis* Zeh

L. ceranoides (a - d)

a) Assimilatory filament

b) 4 celled carpogonial branch

c) Upper cell of fertilized carpogonium dividing into gonimoblast initials.

d) Division of gonimoblast initials resulting into gonimoblast filaments

L. doridis (e - i)

e) Assimilatory filament

f, g) 4-5 celled carpogonial branch

h) Transverse division of fertilized carpogonium resulting into gonimoblast initials

i) Division of gonimoblast initials resulting into cystocarp

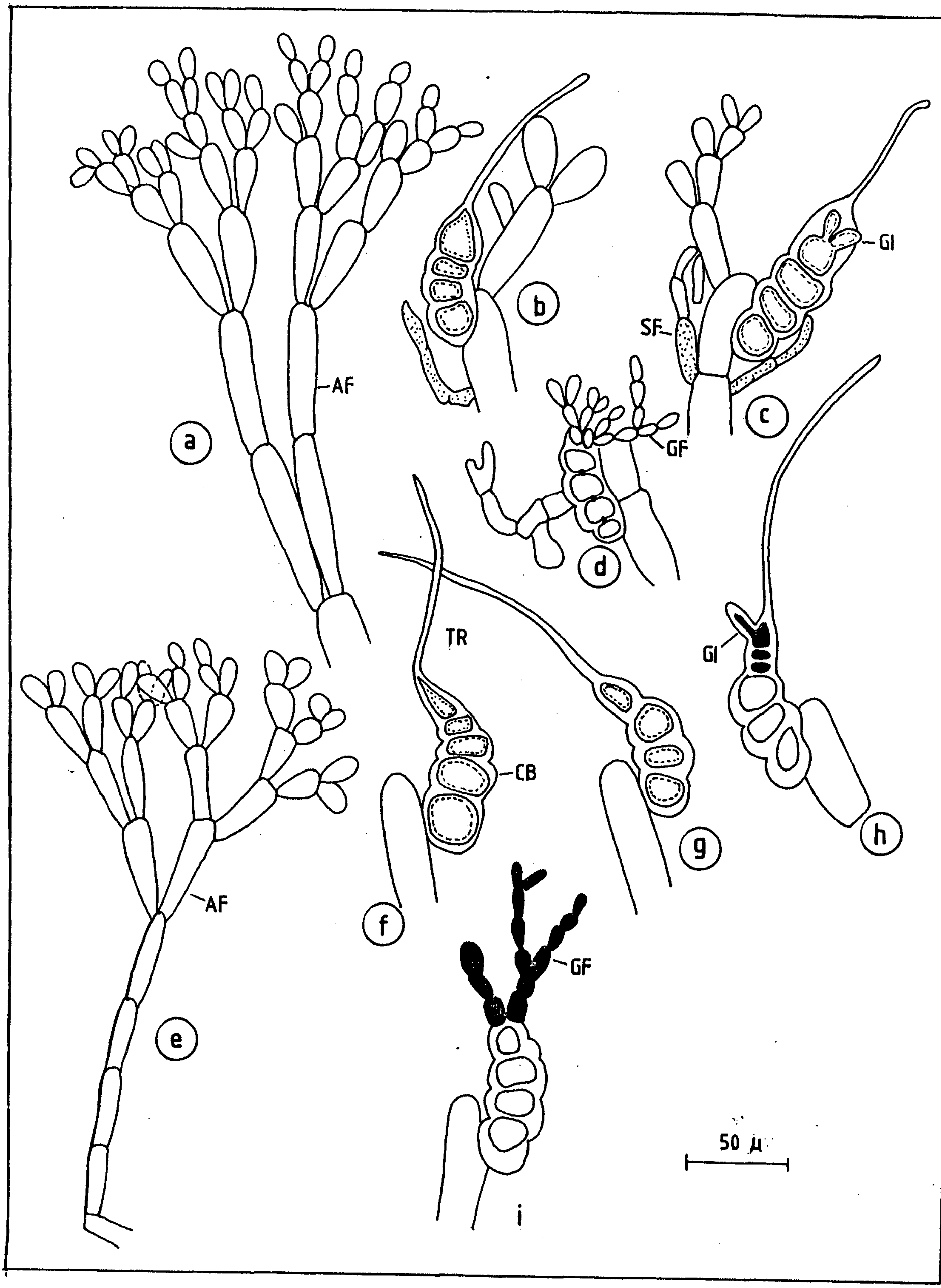


Fig. 18

Anatomy : Thallus shows central medulla which is surrounded by cortex. Cells of Medullary filaments are elongate, cylindrical and measure about 320 x 12-25 um. Assimilatory filaments are 4-6 times dichotomously branched. Reduction in the cell size is observed from base to apex. Cells of the assimilatory filaments measure 50 x 8; 42 x 7; 38 x 6; 24 x 6; 15 x 7 and 8 um respectively. (Fig. 19 a).

Reproduction : *L. indica* is dioecious species. In male plants, distance between furcations is slightly lesser than the female plants.

Spermatangia are borne in loose terminal cluster on the terminal cells of assimilatory filament. 3-5 spermatangial mother cells arise from the upper cells of assimilatory filament (Fig. 19 i). Spermatangium measures 3 um in diameter.

Carpogonial branch is elongate and given out from the middle portion of the assimilatory filament. Carpogonial initial is spherical (Fig. 19 b)which divides to form 3-4 celled carpogonial branch which measures 35-38 um in length (Fig. 19, c, d).

After fertilization, trichogyne is usually cut off and carpogonium divides transversely. From the upper cells, two small gonimoblast filaments are formed (Fig. 19 f) which grow horizontally (Fig. 19 g).

Cystocarp is hemispherical and 177 um in diameter (Fig. 19 h). Involucral filaments are intermixed with gonimoblast filaments. Pit connections between carpogonial branch widen to form fusion cell(Fig. 19 h). Carpospores are terminal, oval and produced singly which are 1Ø x 3 um in size (Fig. 19 h).

d) *L. visakhapatnamensis* Sundararajan

Umamaheswar Rao (1969), P. 2Ø3, PL I, Fig. 1-16.

Habit-Habitat : Grows in the sheltered areas of midlittoral zone. Thalli are soft, mucilagenous, lightly calcified, brownish in colour. Plants are dioecious, dimorphic. Male plants branch in simple manner and do not bear many branchlets (Plate V j). But female plants are densely covered with short branchlets (Plate V i).

Anatomy : Thallus shows multiaxial construction. Assimilatory filaments are 33Ø-52Ø um long and 6-8 times furcated, cells of which have dimension of 3Ø-42 x 9-11 um; 12-15 um respectively (Fig. 19 a).

Reproduction : Assimilatory filaments produce spermatangia in cluster. 1-4 spermatangia are produced from each spermatangial mother cell. Spermatangia are 2-3 um in diameter (Fig. 19 b).

Carpogonial branches are given out laterally from the lower cells of assimilatory filament (Fig. 19 c).

Carpogonium is 2-4 celled (Fig. 19 c,d,e). Carpogonium is conical and bigger than the rest of the hypogynous cells. It measures about 18 x 12 um. Hypogynous cells are broad and 1Ø-15 um x 7-1Ø um in size (Fig. 2Ø e). Trichogyne mostly falls off after fertilization (Fig. 2Ø f).

FIG. 19

<u>Liagora</u> <u>indica</u> Sundararajan (a - i)

a) Assimilatory filament

b) Carpogonial branch initial

c, d) 3,4 celled carpogonial branch

e) Fertilized carpogonium dividing transversely

f) Gonimoblast initials

g) Gonimoblast filaments

h) Mature cystocarp with carpospores & fusion cell

i) Assimilatory filament with spermatangia

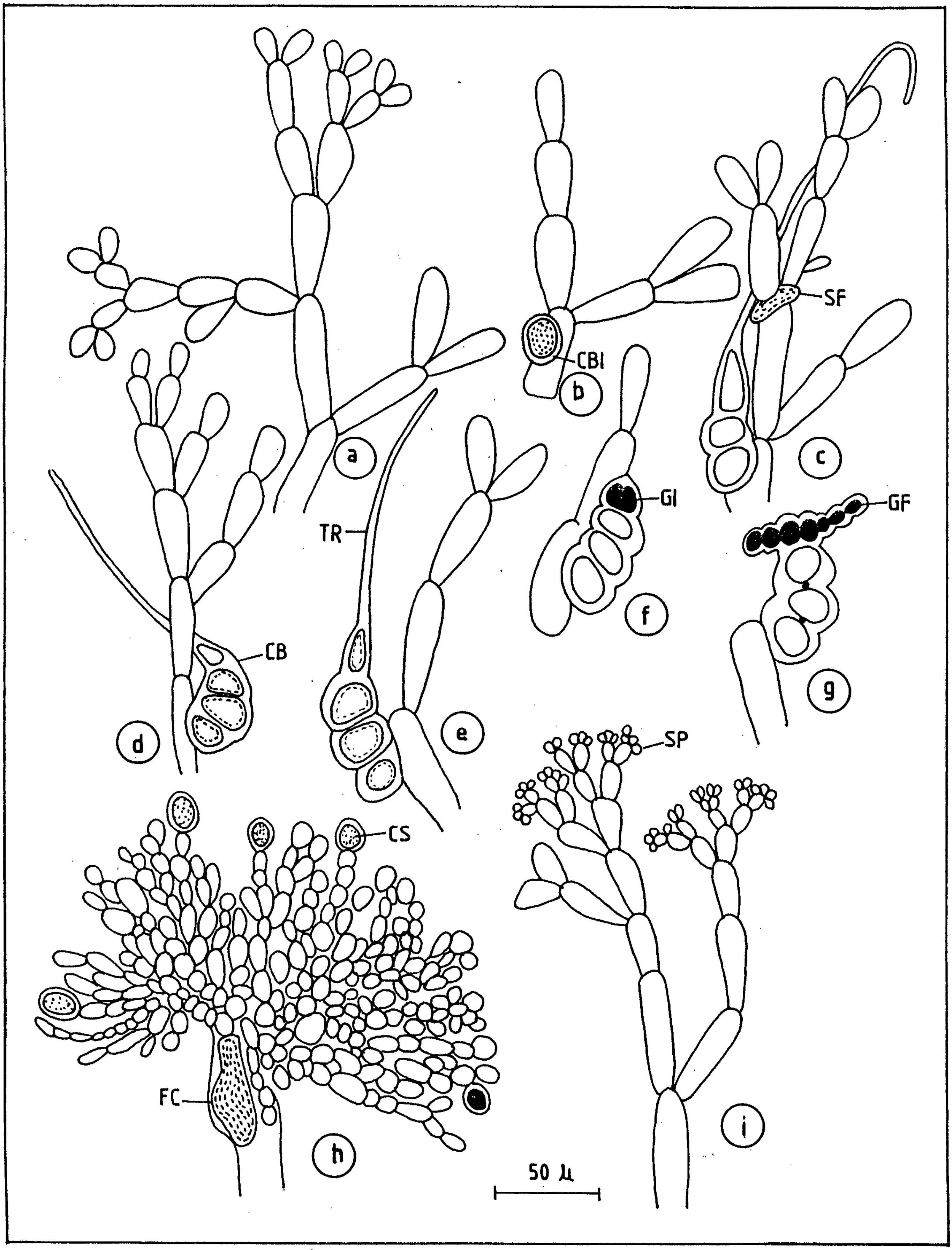


Fig. 19

FIG. 20

<u>Liagora visakhapatnamensis</u> (a - h) Sundararajan

a) Assimilatory filament

b) Assimilatory filament bearing spermatangia

c,d,e) 3,4,5 celled carpogonial branches respectively.

f) Shedding off trichogyne after fertilization

g) Transverse division of fertilized carpogonium

h) Formation of gonimoblast initials.

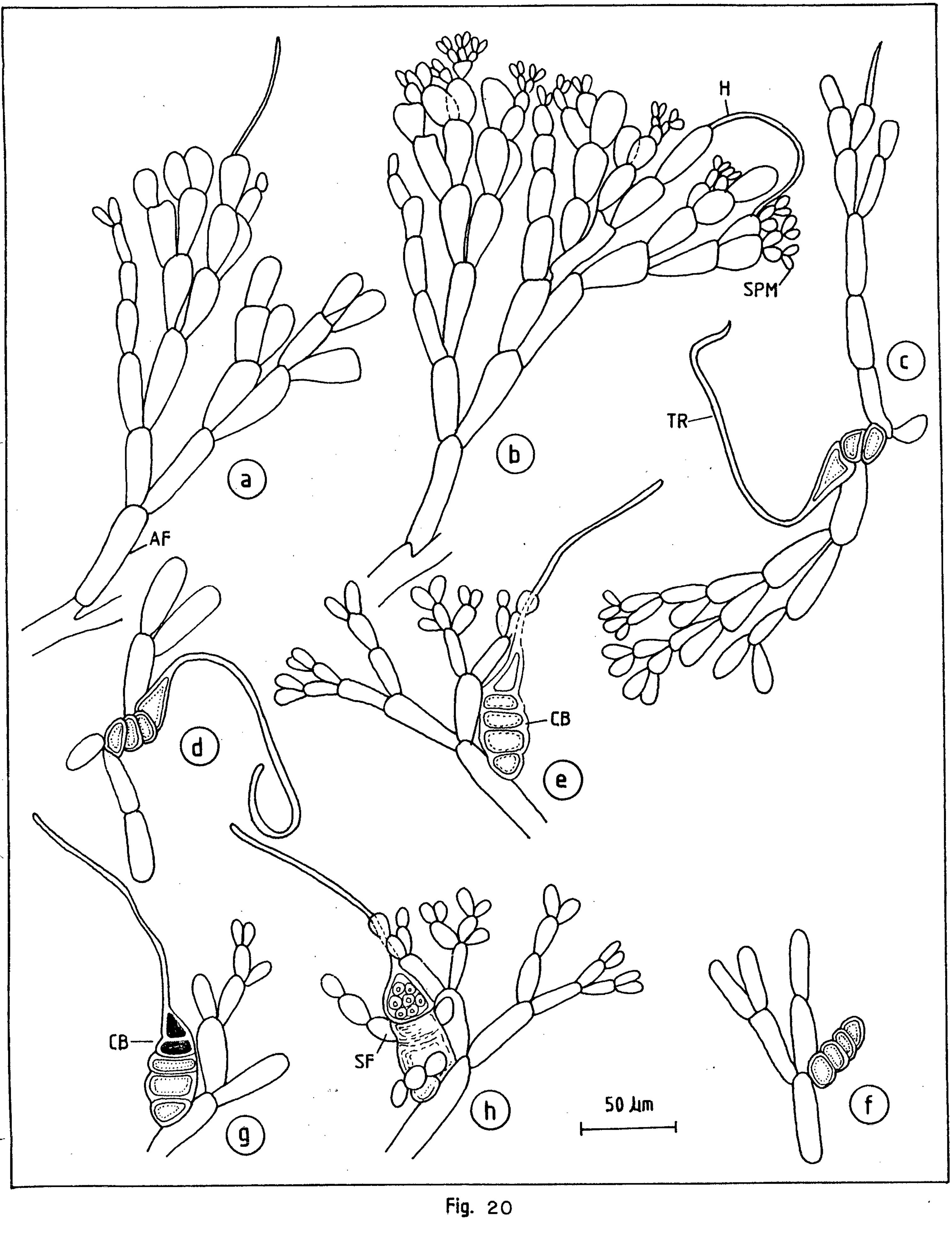


Fig. 20

Fertilized carpogonium undergoes transverse division (Fig. 2Ø,g). Upper cell further divides transversely and longitudinally resulting into the formation of groups of cells which produce gonimoblast initials (Fig. 2Ø h). Further stages were not observed in our specimen.

PLATE V

a) Galaxaura lapidescens (Ell. et. Sol.) Lam.

b) G. lenta Kjellman.

c) G. marginata Lamour.

d) G. rugosa Lamour.

e) G. oblongata Lamour.

f) Liagora ceranoides Lamour

g) L. indica Sundararajan

h) L. doridis Zeh

i) L. visakhapatnamensis (female plant) U. Rao

j) L. visakhapatnamensis (male plant) U. Rao

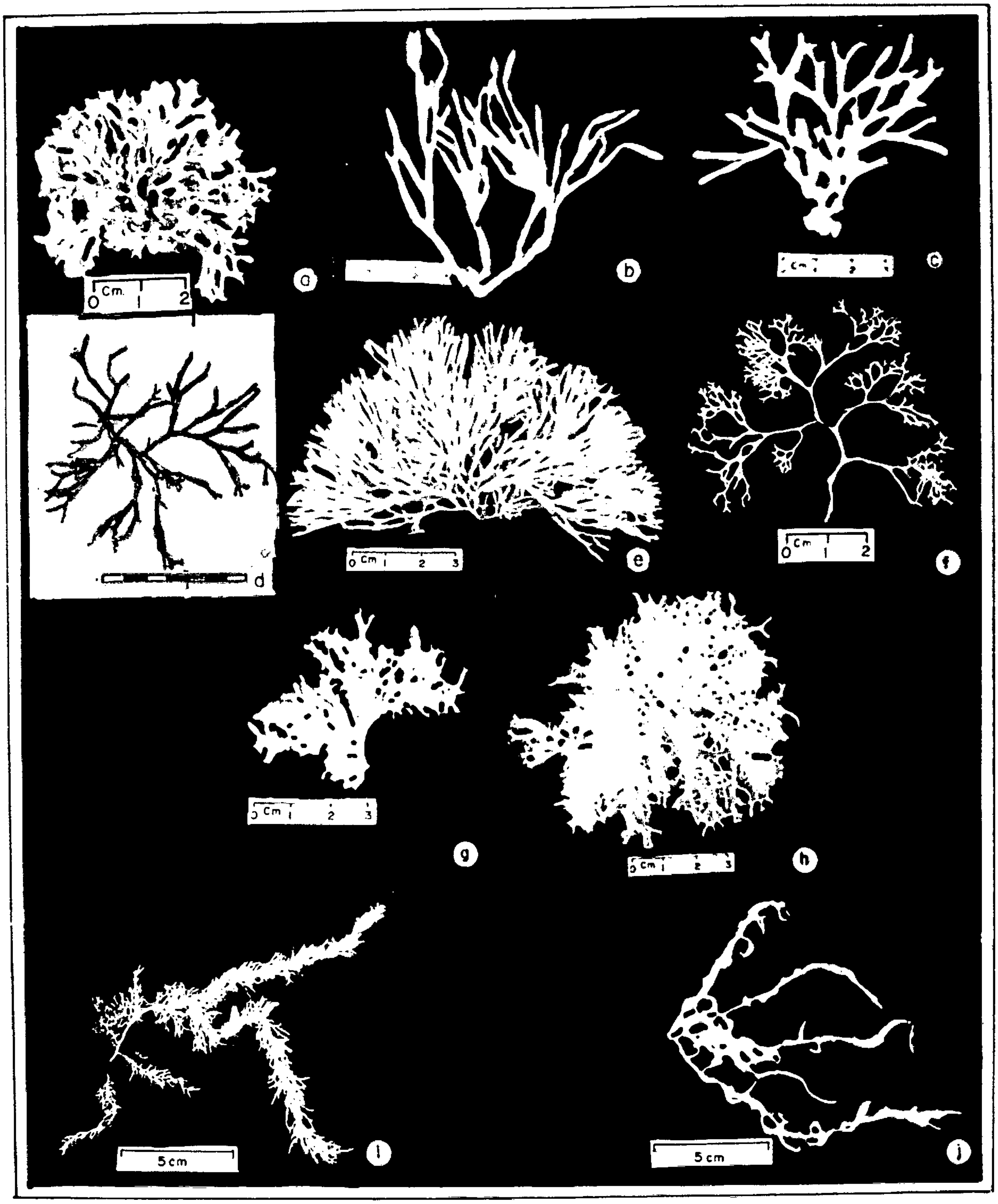


PLATE V

4. AMPHIROA
Lamouroux

Thallus is generally erect, arising from a small basal disk. Branching is di-tri-polychotomous; branches are heavily calcified. Joints are uncalcified. In the central strand, rows of short cells are intercaleted between rows of long cells, all standing vertically one above the other. Nodes are also multizonal. Conceptacles are lateral, sessile and scattered on the segments.

a) A. anastomosans
Weber van-Bosse

W.v. Bosse (1904), P.91, PL. XIV, Fig. 3,4.

Habit-Habitat : Plants are anastomosing irregularly, densely, giving compact and tufted appearance to the plants. Basal crust is indistinct (Plate VI a). Plants light pink in colour.

Intergenicula are cylindrical throughout and of varying sizes 0.5 - 1 cm long and 0.3 - 0.5 mm broad. Genicula are 0.5 - 1.0 mm broad, 0.3 - 0.5 mm long and occur at the base of dichotomies.

Anatomy : Thallus is multiaxial. Apical meristematic cells are covered by single layer of cover cells which have a diameter of 5-8 um (Fig.21 a).

Intergenicular medulla is composed of long and short cells (Fig.21 c). 4-5 rows of long cells alternate with a row of short cells. Long cells are 40-80um in height. Short cells are spherical and measure 9-15 um. The cells of the medullary filaments spread out in fan like fashion and become gradually smaller towards periphery (Fig.21 c). Cortical cells are squarish (Fig.21 d) and measure 10-35 um in length and 8-10 um in width. Single layer of cover cells is also seen in this region (Fig.21 d). Secondary pit connections were commonly observed both among the long and short cells in the medullary and cortical region.

Geniculum is also multizonal consisting of long and short cells. Cells are thick walled (Fig.21 b) and taper gradually towards the end. 4-6 rows of long cells alternate with short cells.

<u>Reproduction</u> :

Tetrasporic conceptacles : Tetrasporic conceptacles prominently protrude out on the surface of intergenicula.

Mature tetrasporangia are 33-55 um long and 12-22 um broad. Mature conceptacles have an outer diameter of 320-480 um, inner diameter of 200-288 um and height of 120-160 um.

Sexual and bisporic plants were not observed in the collection.

FIG. 21

<u>Amphiroa anastomosans</u> (a - e)
W.V. Bosse

a) L.S. through apical region showing cover cells.

b) L.S. through geniculum showing thick walled cells.

c) Intergenicular medulla and cortex showing pit connections.

d) Intergeniculum

e) L.S. through tetrasporic conceptacles.

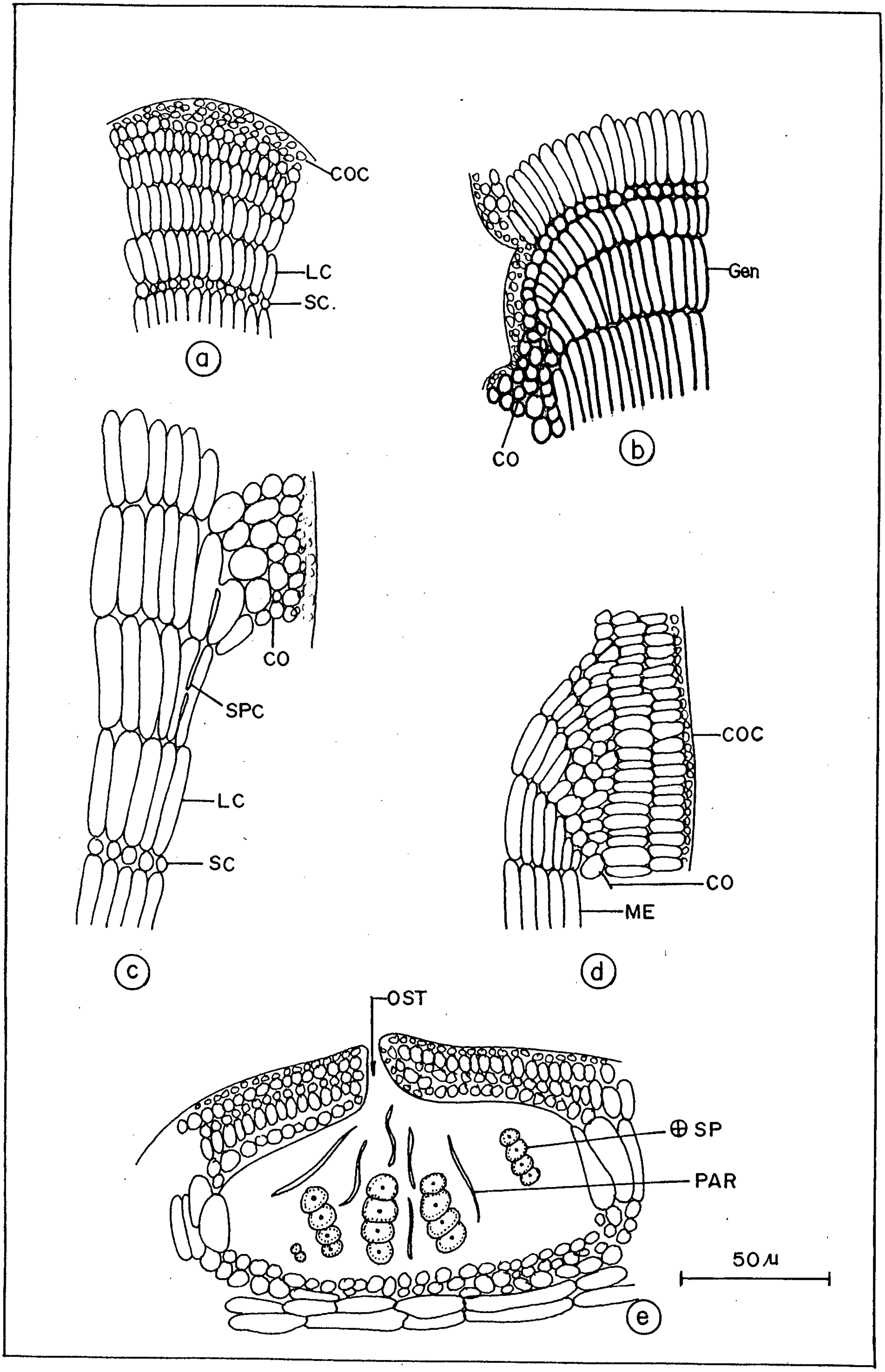


Fig. 21

b) *A. anceps* (Lamk.) Decaisne

W.v. Bosse (1904), P.93, Pl. XVI, Fig.6-8.

Habit-Habitat : This alga mostly grows just below the low water mark; attached by small crustose basal portion; grow upto 5-10 cm and has red to light purple colour. Thalli are branched dichotomously, trichotomies and tetrachotomies are also seen in this alga (Plate VI b).

Intergenicula are 3-8 times as long as broad, mostly upto 2-3 mm in width. They are progressively longer and get compressed distinctly in the upper portions.

Anatomy : Thallus shows multiaxial construction. Meristematic cells at the apex are covered by a single layer of flattened cover cells (Fig.22 a).

Intergeniculum is multizonal and shows the presence of long and short cells. 2-4-6 rows of long cells alternate with a single row of short cells. Very rarely two rows of short cells also occur (Fig.22 d). The height of long cells varies from 30-90 um while that of short cells varies from 9-15 um. From the periphery, medullary filaments spread out in a fan like fashion with the gradual decrease in the size and form a cortex (Fig.22 c). Cortical cells are also covered by a single layer of cover cells . Secondary pit connections between adjacent cells both in medulla and cortex are seen (Fig.22 c).

Geniculum is multizonal and medulla consists of long and short cells and also a cortex. Cells are thick walled (Fig.22

d). The dimension of cells is same as that of intergenicular cells. Pit connections are also seen in genicular region (Fig.22 d).

Reproduction : Plants bearing tetrasporangia are branched vigorously. Tetrasporic conceptacles are prominent and scattered laterally on the surface of intergenicula. Each intergeniculum bears 4-12 tetrasporic conceptacles.

Tetrasporangia in the mature conceptacles are restricted towards periphery. Central portion is filled with a tuft of paraphyses (Fig.22 f). Inner diameter of mature conceptacles is 220-350 um while the outer diameter is 400-510 um and height is upto 75-130 um. Mature tetrasporangium measures 35-50 um x 12 - 20 um.

Female conceptacles : Compared to the tetrasporic conceptacles, female conceptacles are smaller in size and abundant.

Fusion of fertilized carpogonium and process of fertilization was not observed. Only the fully developed long and unbranched gonimoblast filaments were observed (Fig.22,e). From the tip of gonimoblast filaments, spherical carpospores with diameter of 25-35 um are given out (Fig.22 e).

Mature cystocarpic conceptacles have an outer diameter of 400-750 um inner diameter of 150-250 um and height of 130-150 um.

FIG. 22

Amphiroa anceps (a - f)
(Lamk) Decaisne

a) L.S. through apex showing a layer of cover cells.

b) Multizonal geniculum.

c) Intergenicular medulla and cortex showing secondary pit connections.

d) Two rows of short cells in between two rows of long cells in the intergenicular medulla.

e) L.S. through cystocarpic conceptacle showing fusion cell and gonimoblast filaments.

f) L.S. through tetrasporic conceptacles showing tetraspores intermixed with paraphyses.

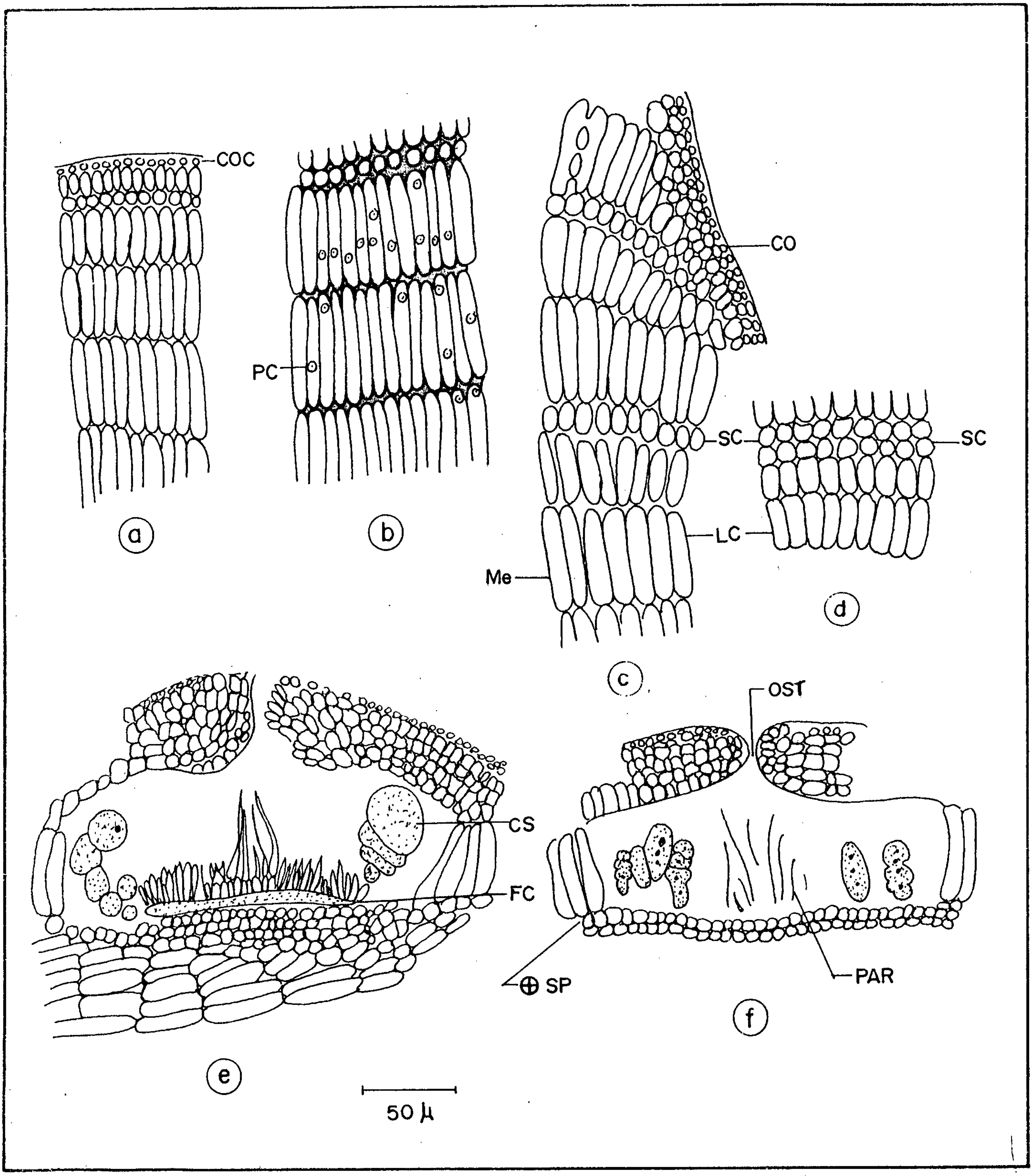


Fig. 22

c) *A. foliacea* Lamour.

W.v. Bosse, (1904), P.92, PL. XIV, Fig.1-11.

Habit-Habitat : Plants are pinkish to light purplish in colour, form a coarse structure on the rocks and reach a height of 2.5 cm. Branching is irregularly dichotomous.

The lower intergenicula are short and cylindrical while upper ones are flattened and broader than long. Length of intergenicula varies from 3-5 mm while width ranges from 2-8 mm (Plate VI c).

Genicula in the lower portions are thick and prominent attaining a breadth of 1-2 mm and length of 2 mm. Geniculum is usually uncalcified but some genicula in the upper portions are partially covered at the sides by calcified cells.

Anatomy : Thallus is multiaxial. As in the species described earlier, the meristematic cells at the apical region are covered by a single layer of cover cells (Fig. 23 a). Medullary filaments are made up of long and short cells (Fig. 23 a). 2-6 rows of long cells alternate with a row of short cells. Long cells attain a height of 30-70 um and width of 5-10 um. The short cells are isodiametric and measure 6-22 um in size. Cortex is well developed and consists of many layers of rectangular cells which are covered by a single layer of cover cells (Fig. 23 c). Pit connections are observed in the medullary and cortical region (Fig. 23 b, c). Genicula are multizonal and consist of long and short thick walled cells (Fig. 23 b).

Reproduction :

Tetrasporic conceptacles : These are scattered laterally and occur on both the surfaces of intergenicula. They are superficial or half immersed inside the tissues of intergenicula.

Outer diameter of mature tetrasporic conceptacles is 440-500 um while, inner diameter ranges from 160-240 um. Height of the conceptacles ranges from 100-130 um (Fig. 23 d).

Early stages in the development of tetraspores were not observed in our specimen.

Sexual plants were not found in collection.

FIG. 23

<u>Amphiroa foliacea</u> (a - d)
Lamour

a) L.S. through apex showing a layer of cover cells.

b) Intergenicular and genicular region.

c) Intergenicular medulla and cortex showing pit connections.

d) L.S. through tetrasporic conceptacles

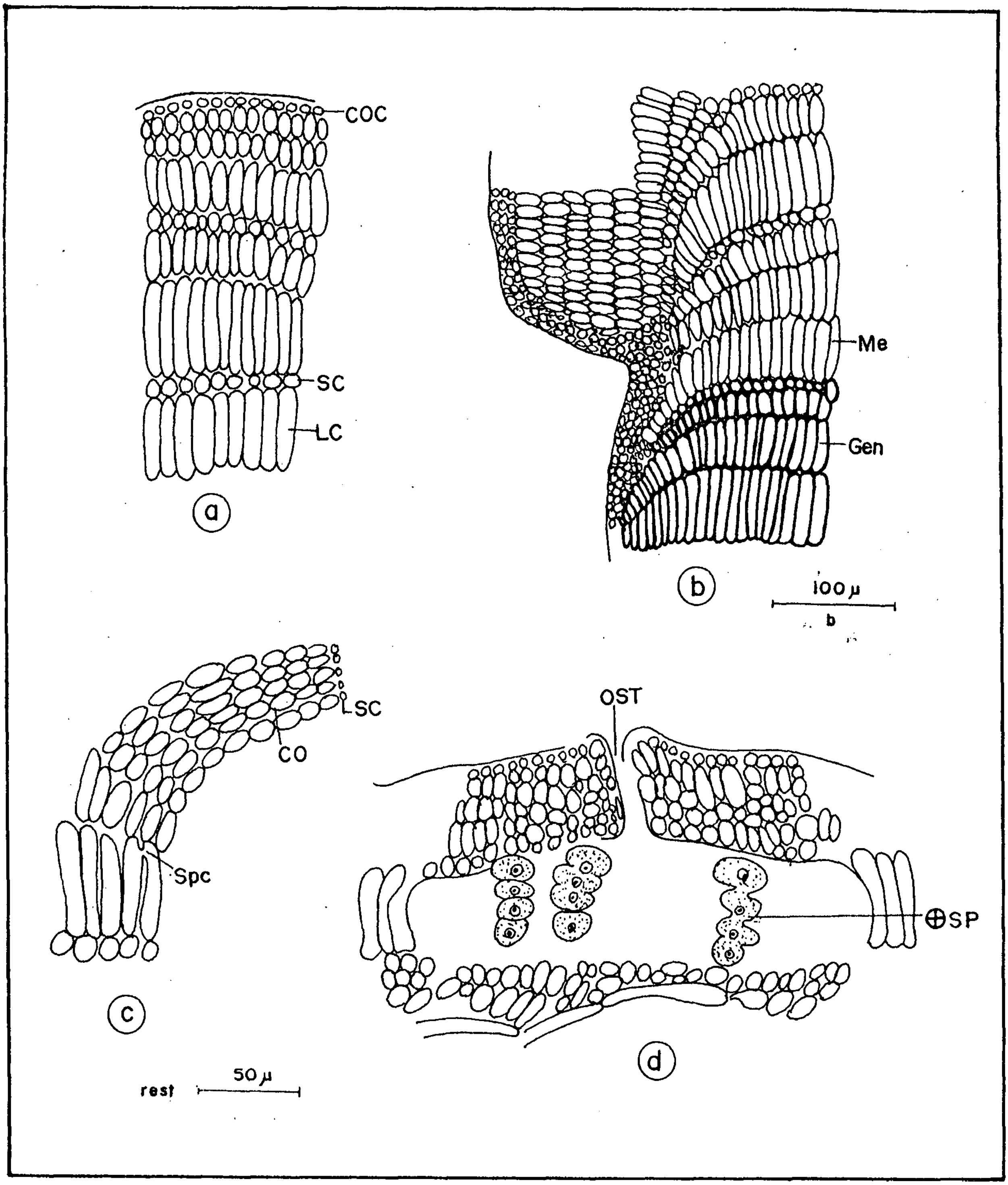


Fig. 23

d) *A. fragilissima* (L.) Lam.

W.v. Bosse, (1904), P.89, PL. XIV, 1,2,5, PL. XIV, Fig. 1, 2.

Habit-Habitat : This alga grows in the lower mid-littoral zone and favours sheltered areas. Thallus is articulate, attaining a height of about 4-6 cm. Fresh specimen have light purple colour. Branching is dichotomous (Plate VI d).

Intergenicula are cylindrical and uniform in diameter. Lower intergenicula are short while upper ones are comparatively longer. Basal genicula are prominent and brownish. Dichotomous branches mostly have common genicula. Geniculum in this alga is swollen padlike.

Anatomy : Structurally, thallus is multiaxial. Meristematic cells at the apical region are covered by a single layer of cover cells (Fig. 24 a) having diameter of 6-8 um. Intergenicular medulla consists of long and short cells (Fig. 24 b). The height of long cells varies from 33-77 um. Short cells have a diameter of 9-13 um. Cells of medullary filaments spread out in fan-like fashion, so become gradually smaller towards periphery (Fig. 24 c).

Cortex varies from feeble to well developed. Cortical cells are circular to squarish. There is a single layer of cover cells which are 4-8 um in diameter. Secondary pit connections are observed in long and short cells in the medullary region of intergenicula (Fig. 24 c).

Geniculum is multizonal and consists of long and short cells. Cells are thick walled and uncalcified (Fig. 24 d).

Reproduction : Though a large number of plants were carefully examined, no sexual and bisporic plants were found in our collection.

Tetrasporic conceptacles : Conceptacles are prominent and not immersed in the frond. They are slightly elliptical or round and 0.5 mm in diameter.

Tetrasporangial mother cells differentiate in the cortical region (Fig. 24 e). Nucleus of the tetrasporangial mother cells divides successively twice and four spores are produced (Fig. 24 f). Tetrasporangia are intermingled with elongate thin paraphyses (Fig. 24 f). Tetrasporangia are 33 - 55 x 15-22 um in size. Mature conceptacles have an outer diameter of 210 - 275 um and height of about 135 - 188 um. Tetraspores liberate to the exterior through "ostiole".

FIG. 24

<u>Amphiroa fragilissima</u> (a - g)
(L.) Lam.

a) L.S. through apex showing a layer of cover cells.

b) Intergenicular medulla showing long and short cells.

c) Intergenicular medulla and cortex.

d) Multizonal geniculum.

e) L.S. through young tetrasporic conceptacles showing tetraspore mother cells.

f) L.S. through mature conceptacles showing tetraspores intermingled with paraphyses.

g) Tetraspores.

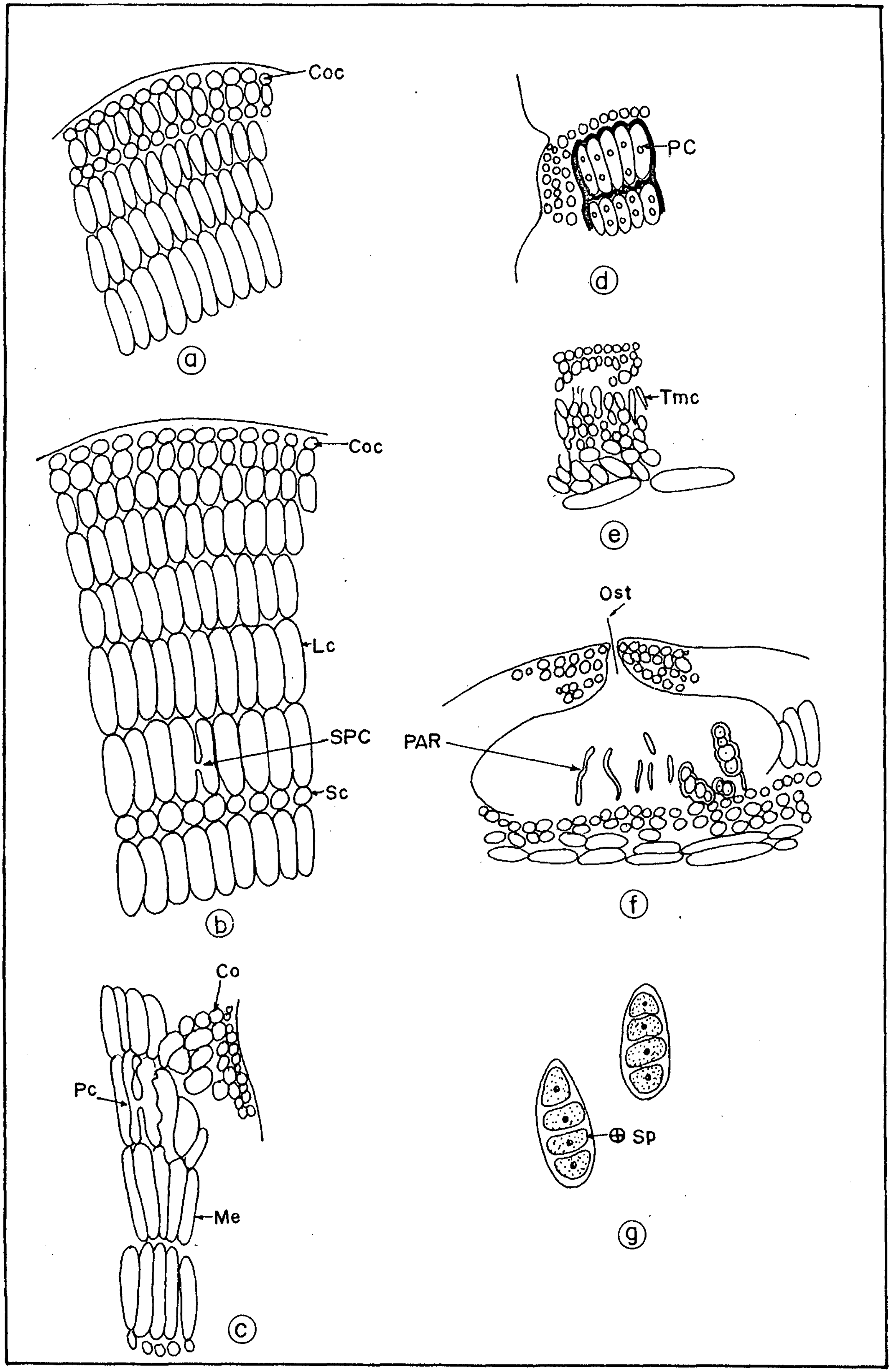


Fig. 24

5) ARTHROCARDIA
Areschoug.

Fronds are branched, articulate. In the central strands all cells have almost the same dimension throughout the whole joint. Node consists of one row of long cells. Joints cylindrical, conceptacles form conical protruberances on the joints.

a) *A. capensis*
(Leach) Areschoug.

Ganesan, (1967b), P.161, PL. I (1,2,5) Fig.1-5.

Habit-Habitat : Plants light pink in colour, 4-5 cm in height. From the basal crust, erect thalli are given out. Fronds are attached to the substratum by means of a basal geniculum. Branching is dichotomous, small proliferations arise from the basal intergenicula. Upper branches end in a flabellate fashion (Plate VI e). Thalli are markedly compressed.

Intergenicula are compressed, 2-4 times longer than broad. The length varies from 1-2 mm and breadth from 0.2 - 0.5 cm. In the upper portion of alga, number of small sterile proliferations with one to many intergenicula are seen. Occasionally these proliferations are replaced by solitary conceptacles.

Anatomy : Thallus is multiaxial. The growth takes place by means of apical cells. The cells of the intergenicular medullary filaments are 32-80 um long and 6-10 um broad. Cortex is made up of 3-6 layers of rectangular to squarish cells and is terminated by a single layer of cover cells (Fig. 25 a).

Secondary cell fusions are occasionally seen both in the medullary and cortical region (Fig. 25 b & c).

Geniculum is multizonal and made up of a single row of elongated and thick walled cells. The geniculum is 160-200 um long and 160-240 um broad (Fig. 25 b).

Reproduction :

Tetrasporic conceptacles - These are borne in small terminal cymoid clusters. 2-5 conceptacles were found in successive furcations. Horn like outgrowths at two lateral sides are developed from basal region of each conceptacles, which result into two more conceptacles without developing into further segment. This process remains continued till 2-5 conceptacles are found in succession. Ultimate conceptacles are sometimes with two antennae or even naked.

Tetrasporic conceptacles have an outer diameter of 120-180 um and the outer diameter corresponds to the width of intergeniculum. Mature tetraspore measures about 100 um in length and 25 um in width (Fig. 25 d).

FIG. 25

<u>Arthrocardia capensis</u> (a - d)
(Leach) Areschoug

a) L.S. through apical region showing apical cells.

b) L.S. through geniculum showing thick walled cells.

c) L.S. showing intergenicular medulla and cortex.

d) Tetraspore.

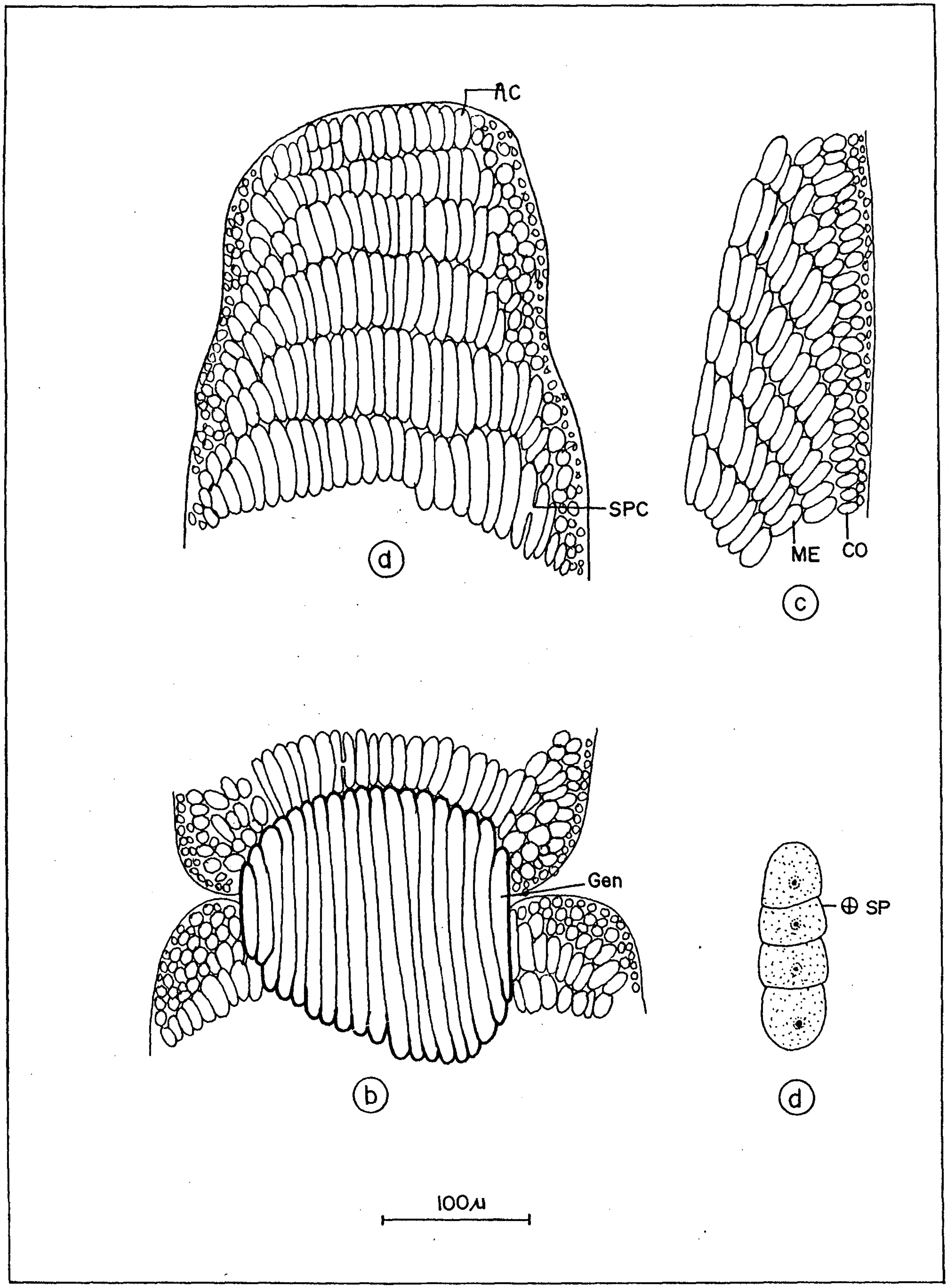


Fig. 25

6) JANIA Lamouroux

Fronds are articulate, branched, erect, arise from a small basal disk. Branching is mostly dichotomous. Joints are cylindrical. In the central strand, all cells have almost the same dimension throughout the whole joint. Nodes consist of one row of long cells. Conceptacles at the growing tip of branches and are immersed in the tissues of joints.

a) J. rubens (L.) Lam.

Suneson (1937), P.37-39, Fig. 13 A-H.

Habit-Habitat : Plants are greyish pink in colour, 2-2.5 cm in height; grow on shells, on rocks in dense tufts (Plate VI f). Basal crust gives rise to 1-5 erect fronds. Branching is dichotomous, profusely branched, apices of ultimate segments are pointed. Intergenicula are uniformly cylindrical from base to the tip, 120-240 um broad, lower intergenicula short and progressively longer in the upper region. Length of intergenicula varies from 240-1000 um.

Anatomy : Thallus is multiaxial. Growth is effected by means of a group of elongated apical cells (Fig. 26 a). The medullary cells are of uniform length and vary from 46-78 um long and 6-10 um broad. Intergeniculum consists of many rows of long cells in transverse rows of equal length. Cortex is very feebly developed, consists of 2-3 layers of squarish to rectangular cells (Fig. 26 b) and is covered by a single layer of cover cells which have a diameter of 9-16 um.

Medullary region and cortex show secondary lateral fusions (Fig. 26 b). Secondary pit connections were not seen.

Trichocytes were observed in this alga (Fig. 26 a). Geniculum is made up of a single zone of cells, i.e. unizonal. Cells are thick walled, broader in the centre and have dimensions of 90-120 x 60 - 120 um.

Reproduction : Tetrasporic plants are profusely branched with a large number of conceptacles.

Tetrasporangial initials are differentiated at the growing tips of alga (Fig. 26 a) which divide transversely into tetrasporangial mother cells and stalk cells (Fig. 26 a). Each tetrasporangium forms four zonate tetraspores (Fig. 26 d,e) by three simultaneous cleavage furrows.

Mature tetrasporic conceptacles have an outer diameter of 200-460 um and inner diameter of 120-240 um. Mature tetraspores are 120-160 x 40-50 um in dimensions. Tetraspores liberate to the exterior through an ostiole (Fig. 26 d).

FIG. 26

<u>Jania</u> <u>rubens</u> (a - e)
(L.) Lam.

a) L.S. showing structure of apical intergeniculum and geniculum; showing group of apical cells and trichocytes.

b) L.S. through intergeniculum showing details of cortex and medulla.

c) L.S. through young tetrasporic conceptacles showing stalk cell and tetraspore mother cell.

d) L.S. through mature tetrasporic conceptacles.

e) Young tetraspore.

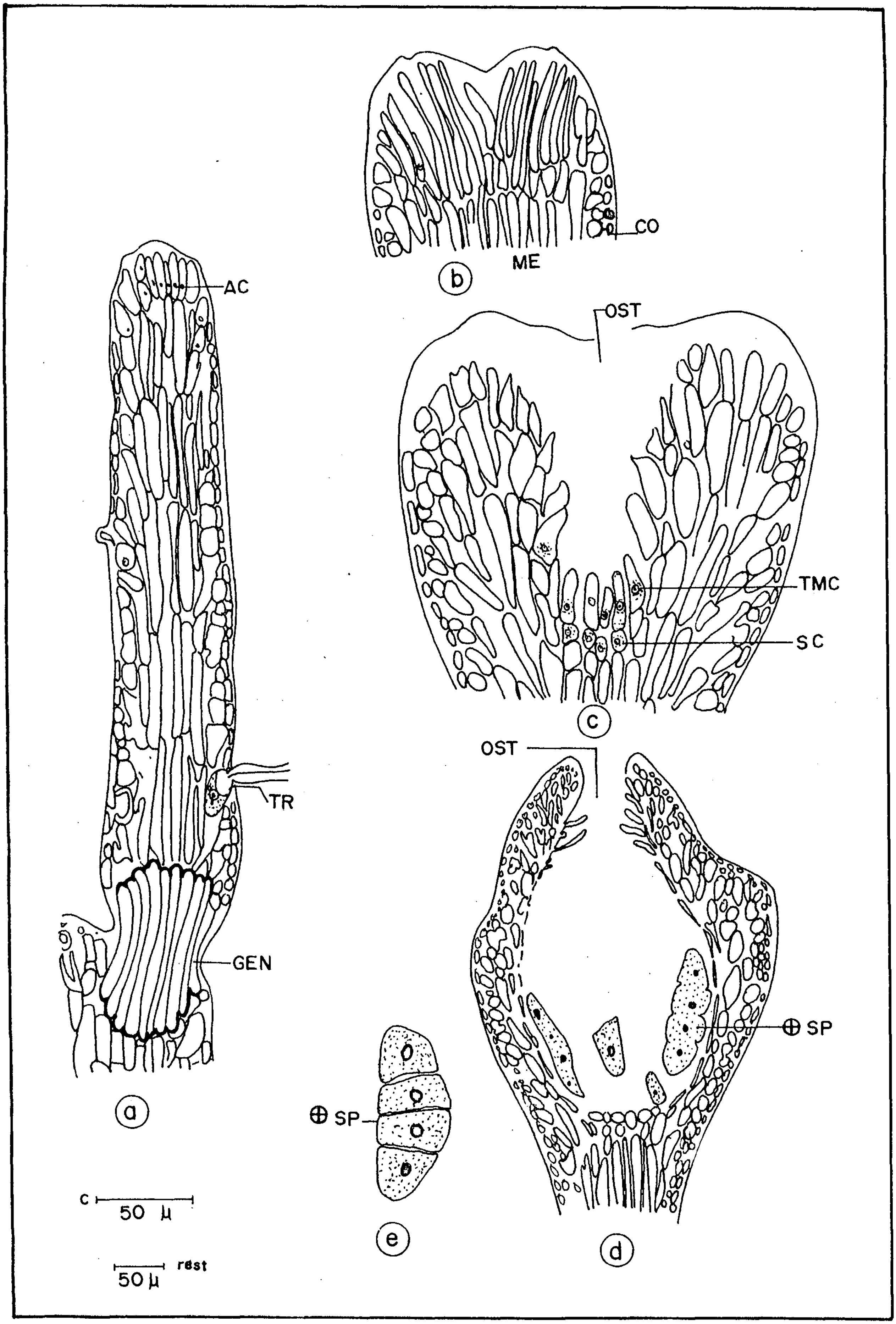


Fig. 26

PLATE VI

a) Habit of Amphiroa anastomosans
W.V. Bosse

b) Habit of A. anceps
(Lamk.) Decaisne

c) Habit of A. foliacea
Lamour

d) Habit of A. fragilissima
(L.) Lamk.

e) Arthrocardia capensis
Areschoug

f) Jania rubens
(L.) Lamk.

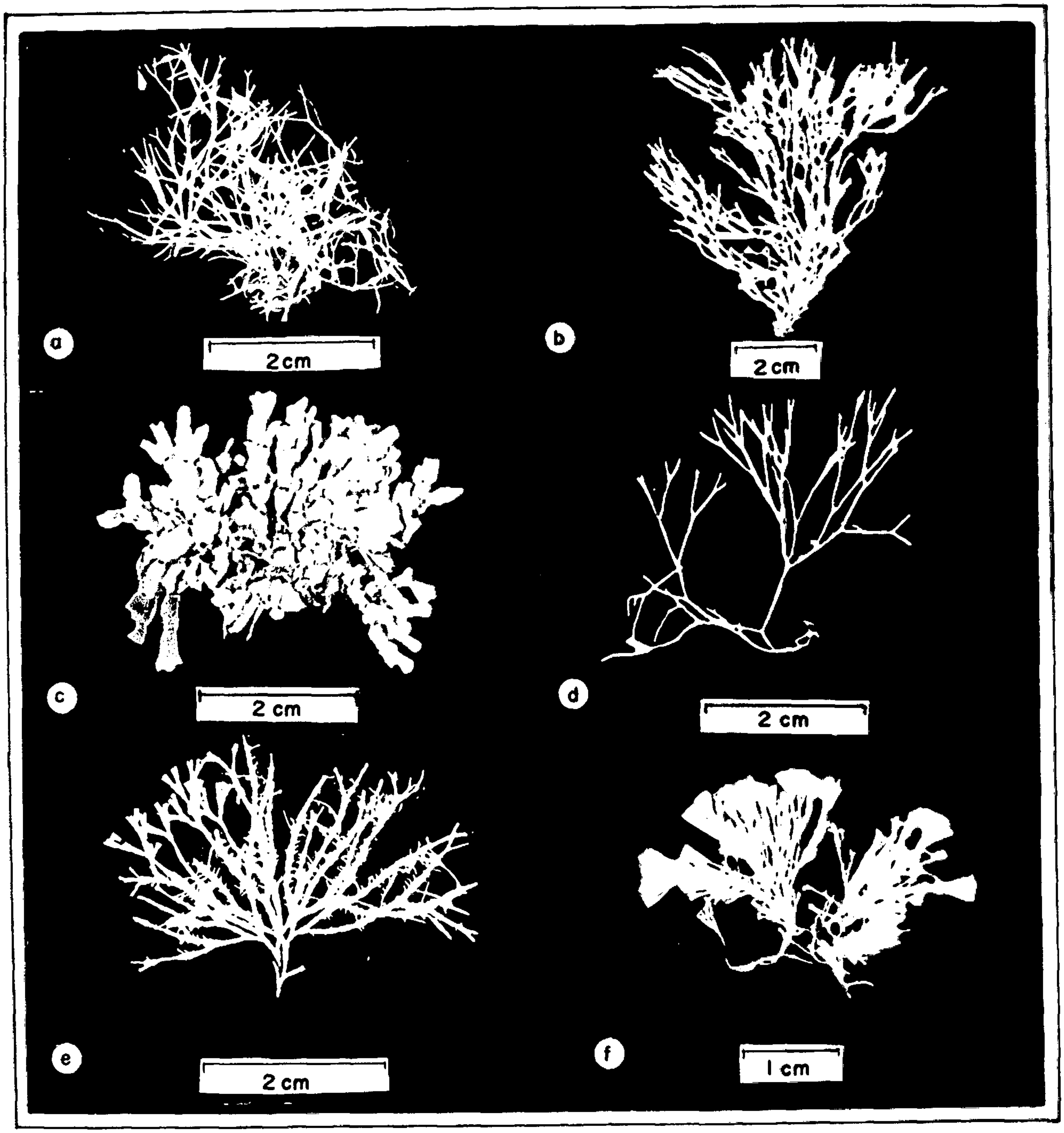


PLATE VI

DISCUSSION

In the present chapter, an account of 33 calcified algae (which includes 14 species of Chlorophyceae, 3 species of Phaeophyceae and 16 Rhodophycean forms) is given. The genera undertaken for study are characteristic of the families which they represent. Seven species of *Halimeda* are described in the present account. Macroscopic characters such as appearance of segment, appearance of holdfast, appearance of thallus and microscopic characteristics like patterns of medullary filaments at the node, size and appearance of primary, secondary and tertiary utricles patterns of cortex and extent of it's development are of taxonomic significance. Segments are compressed, discoidal to reniform with entire upper margin in *H. discoidea*, *H. macrolaba* and in *H. tuna* while in *H. opuntia* and *H. gracilis*, segments are reniform or triangular with wavy margin. Reniform, shallowly lobed with undulate or entire margined segments occur in *H. simulans*.

Bulbous holdfast bigger than 1 cm occurs in *H. macroloba*, *H. simulans* while in *H. opuntia*, holdfast is smaller than 1 cm and obscure. In case of *H. tuna*, *H. discoidea*, *H. gracilis*, holdfast is longer than 1 cm and very inconspicuous.

In *H. macroloba*, *H. simulans*, nodal medullary filaments fuse and form a single unit. In *H. opuntia* and *H. gracilis*, filaments fuse mostly in pairs for a short distance. Filaments fuse in groups for 1.5 to several times of filament diameter.

Inner utricles are generally globular to subglobular in *H. macroloba*, *H. simulans*. In case of *H. opuntia*, inner utricles are not particularly expanded but fairly of uniform diameter throughout and form series to series. While inner utricles expand in various ways in *H. tuna*, *H. discoidea* and *H. gracilis*.

J. Agardh (1887) divided this genus into four sections based on the appearance of segments viz. 'Tunae', 'Pseudo-opuntia', 'Opuntiae', 'Rhipsales'. According to Hillis (1980), pattern of the medullary filaments at the nodes is the obvious characteristic and so she divided this genus into five sections viz. 'Rhipsalis', 'Opuntia', 'Halimeda', 'Micronesica', 'Crypticae'. She has classified

H. macroloba and *H. simulans*	Rhipsalis
H. opuntia	Opuntiae
H. discoidea, *H. gracilis* & *H. tuna*	Halimeda

Our results are in agreement with Hillis (1980). *H. tuna* f. *platydisca* which is reported here for the first time was observed to be restricted to the deeper water areas. This species differs from *H. tuna* in having larger segments and having large surface diameter of their peripheral utricles i.e. upto 125 um in surface view.

Udotea flabellum and *U. indica* agree well in all respects with Gepp (1911) and Boergesen (1930).

Neomeris annulata and *N. van-Bosseae* described here are in agreement with Egerod (1952). *N. van-Bosseae* is reported here for the first time along Indian coast, it differs from the previous one in bearing globose and free gametangia. According to Egerod (1952), N. van-Bosseae and N. dumetosa might be readily confused. But the manner of calcification and orientation of branches are different. Howe (1909), pointed out that in N. van-Bosseae, primary branches remain free even though they are strongly calcified or may be loosely or irregularly coherent while in N. dumetosa, primary branches are firmly cemented together by the deposit of lime. So also N. van-Bosseae is stouter in proportion and 6-12 times as long as broad in contrast to N. dumetosa which is 15-20 times as long as broad.

N. dumetosa is just enlisted from the Indian coast but not described.

N. annulata is described from Gujarat (Patel and Francis, 1970). Specimen described here is in agreement with them.

Species of Padina are studied by Thivy (1959). Number of cell layers in the blade, development of hair lines distribution; presence and persistance of indusium; distribution of sexes; calcification on surfaces of blades are of taxonomic significance. Species described here are in agreement with Misra (1966) and Lewmanomont (1980).

Papenfuss et. al. (1982) revised the genus Galaxaura with special reference to the species occurring in the western Indian Ocean. Species of Galaxaura described in the present account are in agreement with Papenfuss et. al., (1982). Galaxaura rugosa is just enlisted but no description of Indian form is available.

Vegetative details of _G. rugosa_ are given in this account. _G. rugosa_ shows distinct rugose thallus and fusion of cell in the cortical region.

According to Boergesen (1949), Papenfuss and Chiang (1969), _G. fastigiata_ and _G. oblongata_ are identical species. On the other hand Svedelius (1945) opines that, _G. oblongata_ and _G. fastigiata_ should be maintained as separate but closely related species. Krishnamurthy and Sundararajan (1986) also support the view of Svedelius (1945) as there is difference between two species in the site of Calcium Carbonate encrustation. Deposition of lime is exclusively restricted to the cortex in _G. fastigiata_ while in _G. oblongata_, it extends still further towards the interior part i.e. towards epidermal region.

According to Svedelius (1945), the calcification occurs with a certain regularity and uniformity which cannot be only accidental and is dependent on the specific nature of the species. He (1953) also believes that calcification may depend partly on the external factors such as habitat and also on the age of thallus.

Papenfuss _et. al._, (1982) have synonymised _G. fastigiata_ under _G. oblongata_ considering the only gross morphological and anatomical features and neglected the extent and density of calcification. Svedelius (1945), after examining many species of _G. oblongata_ and _G. fastigiata_ differentiated these two species on the basis of localization of calcification. According to Boergesen (1949), specimen growing in the exposed and sunny localities get more encrusted than in the sheltered and shaded places. But Krishnamurthy and Sundararajan (1986) studied G. fastigiata from widely separated localities and found that calcification is always restricted to the cortical portion of thallus.

G. oblongata described here also showed the calcification in the peripheral part of medulla so agreeing with Svedelius (1945) and Krishnamurthy and Sundararajan (1986).

Sundararajan (1984) gives a detailed account of Actinotrichia fragilis collected from Andamans. Species described in the present account is from Lakshadweep and showed no anatomical and morphological differences. But striking differences were observed in the reproductive features. While describing the position of tetrasporangia, Sundararajan (1984) wrote, "Tetrasporangia are borne singly and terminally on an assimilatory filament. Compared to the normal assimilatory filaments, the tetrasporangial branches are very short i.e. they are only three celled". He further stated that his description is in agreement with Svedelius (1952). But our specimen showed that the assimilatory filaments bearing tetrasporangia are considerably long i.e. 10-15 celled and also branched (Plate IVc,d). So also, these branches showed 3-4 lateral branches and each branch bears tetrasporangia terminally and singly (Plate IV d), the nucleus of which divides meiotically resulting into the formation of four tetraspores. Tetrasporangial mother cell is spherical and bigger in size compared to the other cells of the assimilatory filaments.

As far as the cystocarpic plants are concerned, till today no information was available about the cystocarpic development of this genus. Svedelius (1952) wrote, "Weber van Bosse's (1928, PL.VI.1) is the picture of a ripe cystocarp we have of the female organs of Actinotrichia. Neither figure nor the description by Weber van Bosse gives any information on the development which however may possibly proceed in a way similar to that of Scinaia". Our results show that gonimoblast filaments in Actinotrichia are surrounded by sterile filaments so differs from Galaxaura and resembles other members of family chaetangiaceae i.e. Scinaia and Pseudogloiophloea. So our results confirm the guess of Weber Van-Bosse (1928) and Svedelius (1952).

Species of Liagora from the Indian region are studied by Balakrishnan (1955), Desikachary and Balkrishnan (1957), Umamaheshwara Rao (1969), Krishnamurthy and Sundararajan (1987). Desikachary and Balakrishnan (1957) described the post fertilization stages in L. erecta Zeh, where a definite fusion cell involving the cells of the carpogonial branch is formed as in L. viscida & L. maxima. Desikachary and Balkrishnan (1957) have summarized the post fertilization changes in Liagora as : "The fertilized carpogonium in all species undergoes a transverse division. Of the two resultant daughter cells, the upper alone takes part in the formation of the gonimoblast filaments, then there is either widening of the protoplasmic connections between the different cells of the carpogonial branch and the supporting cells (L. papenfusii, L. viscida, L. ceranoides, L. mucosa) or the formation of a distinct fusion cell (L. maxima, L. erecta, L.

harveyana). Involucral filaments are formed in all species of Liagora.

Umamaheshwara Rao (1969), described L. visakhapatnamensis, a new species of Liagora. He found variation in the habits of male and female thalli. The main axis and the branches of male thalli are simple and not covered with short branches. Involucre is not prominent and occurs below the cystocarp without encircling the gonimoblast. So resembles Liagora abottae described by Dawson (1952). L. visakhapatnamensis described here is from Krusadai islands and shows no difference to that species described from Visakhapatnam coast (Umamaheshwara Rao, 1969).

Sundararajan (1984) has described Liagora indica, a new species of Liagora, differs from other species of Liagora in having :

a) Horizontal growth of gonimoblast initial.

b) Carpogonical branch is 4-5 celled and tapers gradually from base to apex.

c) Every cell of the assimilatory filament is shorter than the lower adjacent cell.

d) Proliferations are completely absent.

Species described here is from Krusadai and is in agreement with Sundararajan 1984.

Four species of Amphiroa viz. A. anceps, A. anastomosans, A. foliacea, A. fragilissima agree well with Weber van-Bosse (1904).

1. In all the species, meristematic cells are covered by a single layer of cover cells.

2. Presence of multizonal genicula and intergenicula made up of long and short cells. In A. anceps, 3-6 layers of long cells alternate with a row of short cells, while in A. anastomosans and A. fragilissima, 4-5 rows of long cells alternate with a row of short cells while 2-4 rows of long cells alternate in A. foliacea. Secondary pit connections were observed in the intergenicular and genicular region. But cell-fusions were not observed.

3. As far as the conceptacles are concerned, they are scattered laterally either on one or both the surfaces of the conceptacles.

4. In the tetrasporic conceptacles, tetraspores in case of A. foliacea, A. fragilissima, A. anastomosans arise from the entire floor of the conceptacles while in A. anceps tetrasporangia restrict towards periphery which is similar to A. misakiensis (Segawa, 1940 b).

5. In A. anceps, two carpogonial branches occur on the same supporting cell and shows absence of any supporting cell which is reported in A. foliacea (Ganesan, 1967a). Similarly in A. anceps, gonimoblast filaments are produced from the periphery of fusion cell but Ganesan (1967a) found that there is only one carpogonial branch and lateral sterile cell in A. foliacea.

6. As far as the production of gonimoblast filament is concerned, in case of A. anceps, gonimoblast filaments are produced only from the periphery of the fusion cell. But in A. foliacea, they arise not only from the periphery but also from the upper surface of the fusion cell.

7. Spermatangia in case of A. anceps and A. foliacea arise from the floor of the conceptacles (Ganesan, 1967a).

The details of the above species studied here agree with the accounts given for A. rigida (Suneson 1937, Segawa 1940 a) and A. misakiensis (Segawa, 1940 b). Segawa (1941 a & b) gave the details of A. aberrans and A. crassissima which differ in many respects from the above four species studied here. Based on these details, the differences between our species and A. aberrans and A. crassissima are

1. Absence of cover cells above the meristematic cells.

2. Row of short cells is absent and medullary filaments are of uniform length.

3. Unizonal geniculae are made up of long cells.

4. Secondary pit connections are absent.

5. Secondary cell fusions are present.

6. Lateral and subterminal conceptacles are observed in A. aberrans, while marginal conceptacles in A. crassissima.

7. Basal and lateral walls of conceptacles take part in the

formation of spermatangia. So differ markedly from the other species of Amphiroa.

Weber van-Bosse (1904), after a careful study of anatomical details, pointed out that all species of Amphiroa have a layer of cover cells. She has also emphasized that there is a variation in number of rows of long cells alternating with a row of short cells and the geniculae are mostly multizonal but very rarely unizonal.

The detailed account given by Segawa (1941 a & b) for two species of Amphiroa i.e. A. aberrans and A. crassissima differs in many aspects from other species of Amphiroa.

The delimitation of the genus suggested by W.V. Bosse (1904) has been accepted by most of the workers (Manza, 1940; Hamel and Lemoine 1953; Taylor 1960).

Jania iyengarii and J. rubens are the only species of Jania known from India (Boergesen, 1934 a, 1935, 1938 a). Dixit (1940) has reported J. rubens from India. J. iyengarii is studied in detail by Ganesan (1965). Lamouroux (1812, 1816); Areschoug (1852); Yendo (1902 c, 1905 b); W.V. Bosse (1904) placed the genus Jania under Corallina . But Hamel and Lemoine (1953), Dawson (1953), Kylin (1956) and Taylor (1960) treated Jania as an independent genus following Manza's treatment (1940), (C.f. Ganesan, 1965).

Structure and reproduction have been studied in detail only in J. rubens (Suneson, 1937) and J. radiata (Segawa, 1946). J.

rubens described here is in agreement with Suneson (1937). Our specimen showed only tetrasporic conceptacles. But the procarpic conceptacles and the details of post fertilization are given by (Suneson, 1937). Similar pre and post fertilization developments are observed in J. iyengarii (Ganesan, 1965).

According to Manza (1940), the genus Arthrocardia is the temperate genus but it is reported from Brazil (Taylor, 1960). Ganesan (1967 b) studied A. capensis from Gujarat. Our species showed close morphological and anatomical similarities to the species described from Gujarat, so agreeing well with (Manza, 1940 and Ganesan, 1967 b).

CHAPTER 4

MINEROLOGY AND SURFACE MORPHOLOGY

I. INTRODUCTION :

It is well known, that almost all algal phyla have some genera which have ability to deposit various inorganic substances within or around the cell. However, the predominant mineral deposit of algae is calcium carbonate in the form of 'calcite' and 'aragonite' (Vinogradov, 1953), (see Table 1). Density of forms and organization among the various calcium deposits are studied by X-Ray diffraction and by chemical analysis (Baas-Becking and Galliher, 1931; Perkins et. al., 1972). Lowenstam (1955) and McConnell and Hillis (1967) studied the mineral components of udoteacean members. Aragonite deposits in the members of nemaliales and in the genus Padina are studied by Levy and Strauss (1960), Lowenstam (1955) and Borowitzka (1982). Calcite deposition in the calcified members of cryptonemiales is studied by Vinogradov (1953), Levy and Strauss (1960), Borowitzka et. al. (1974). Site of $CaCO_3$ deposition varies from genus to genus (Table 1).

Aspects of the structure and organization of the deposits of caulerpales are studied by Marszalek (1971) using Scanning Electron Microscopy. Bailey and Bilasputra (1970) studied Corallina and Calliarthron with SEM. Borowitzka et. al. (1974) studied the structure and organization of the $CaCO_3$ deposits of algae. The introduction of SEM in the taxonomy of coralline algae was first proposed by Garbary (1978) and subsequent studies Garbary and Scagel (1979), Garbary & Veltkamp (1980), Garbary et. al. (1981), have shown that this tool offers a great potential.

Garbary and Johansen (1982) showed that two distinctive surface morphologies exist in the sub family Corallinoideae.

All species of calcified algae of India have so far remained uninvestigated for their minerological aspects. So also the structure and organization of these forms have remained unknown. In the present work, an attempt is made to study their calcium deposits.

II. MATERIALS AND METHODS

A) X-Ray Diffraction : Dry powdered samples of calcified algae were analysed for determining the nature of calcium by using Philips X-Ray Diffractometer (No.1840) using Nickel filtered Cu K α radiation. The samples were scanned from 24° to 35° 2θ (The instrumental conditions were 40 Kv and 20 mA).

The minerals were identified using JCPDF cards (Joint Commission of Powder Diffraction File).

B) Scanning Electron Microscopy : To study the surface morphological features, air dried specimens of *Amphiroa*, *Arthrocardia*, *Cheilosporum*, and *Jania* were coated with gold palladium (as suggested by Garbary and Johansen, 1982), while species of *Liagora*, *Galaxaura*, *Halimeda*, *Udotea*, *Actinotrichia* were dehydrated slowly through acetone grades. These species were first coated with carbon and then with gold to avoid excessive charging (Borowitzka *et. al.*, 1974). The observations were carried out with Cameca CAMEBAX Model 571 Electron Probe Microanalyser.

III. RESULTS

A) Minerological features

Diffraction patterns produced by all Chlorophycean forms, *Padina* (Phaeophyceae) and by members of nemalionales (Rhodophyceae) were attributable to aragonite while calcite was the predominant deposit in the members of the family Corallinaceae (Rhodophyceae).

Identified mineral deposits of the species studied are listed in Table 8. Diffraction patterns produced by these forms are represented in Figs. 27, 28 and 29.

B) Surface morphological features

1) Chlorophyta

Halimeda tuna, *H. opuntia*, *H. simulans* showed that needles of aragonite completely fill up the intercellular spaces of the segments. In *H. tuna* crystals were 10.0 um long and 0.3-0.6 um in width (Plate VII a) while in *H. simulans* mature crystals were of uniform size and about 0.08-0.3 um wide and 4-4.5 um long. Needles taper slightly near the ends (Plate VII b,c).

Orientation of crystals in all these species appeared to be random. Deposition of these crystals was observed outside the cell wall but within the intercellular spaces (Plate VII b).

In case of *Udotea indica* and *U. flabellum* aragonitic needles were outside the cell wall but within the sheath. These needles were of 0.07 x 0.4 um in size and occur in bundles (Plate VII d,e).

Table 8 Minerals deposited in the species studied

	Species studied	Peaks produced at (2θ) and identified minerals
1.	*Halimeda discoidea*	26.30 - Aragonite
		27.29 - Aragonite
		31.80 - Halite
		33.19 - Aragonite
2.	*H. gracilis*	26.35 - Aragonite
		26.38 - Illite
		27.71 - Feldspar
		33.34 - Aragonite
3.	*H. incrassata*	26.36 - Aragonite
		27.85 - Feldspar
		31.82 - Halite
4.	*H. opuntia*	26.12 - Aragonite
		26.61 - Quartz
		26.75 - Quartz
		31.66 - Halite
		33.15 - Aragonite
5.	*Udotea indica*	26.36 - Aragonite
		27.32 - Aragonite
		31.86 - Halite
		33.21 - Aragonite

Table 8 (contd.)

6.	Acetabularia Kilneri	26.45	- Aragonite
		26.95	- Quartz
		27.44	- Aragonite
7.	Padina pavonica	26.65	- Quartz
		26.98	- Quartz + Illite
		27.71	- Feldspar
		33.64	- Aragonite
8.	Actinotrichia fragilis	26.35	- Aragonite
		27.32	- Aragonite
		29.96	- High magnesium calcite
		31.81	- Halite
		33.25	- Aragonite
9.	Galaxaura lapidescens	26.32	- Aragonite
		29.98	- High magnesium calcite
		31.78	- Halite
		31.91	- Halite
		33.24	- Aragonite
10.	G. lenta	26.33	- Aragonite
		27.35	- Aragonite
		28.45	- Feldspar
		29.94	- High magnesium calcite
		31.81	- Halite

Table 8 (contd.)

11.	*G. marginata*	26.26	- Aragonite
		27.27	- Aragonite
		28.41	- Feldspar
		29.87	- High magnesium calcite
		31.75	- Halite
12.	*G. oblongata*	26.27	- Aragonite
		27.23	- Aragonite
		28.38	- Feldspar
		31.76	- Halite
13.	*Amphiroa anastomosans*	26.18	- Quartz
		26.72	- Quartz
		29.98	- High magnesium calcite
14.	*A. foliacea*	29.93	- High magnesium calcite
15.	*A. fragilissima*	29.90	- High magnesium calcite
16.	*Cheilosporum spectabile*	29.88	- High magnesium calcite
17.	*Jania rubens*	26.19	- Aragonite
		27.22	- Aragonite
		29.80	- High magnesium calcite
		29.91	- High magnesium calcite
		31.68	- Halite
		33.12	- Aragonite

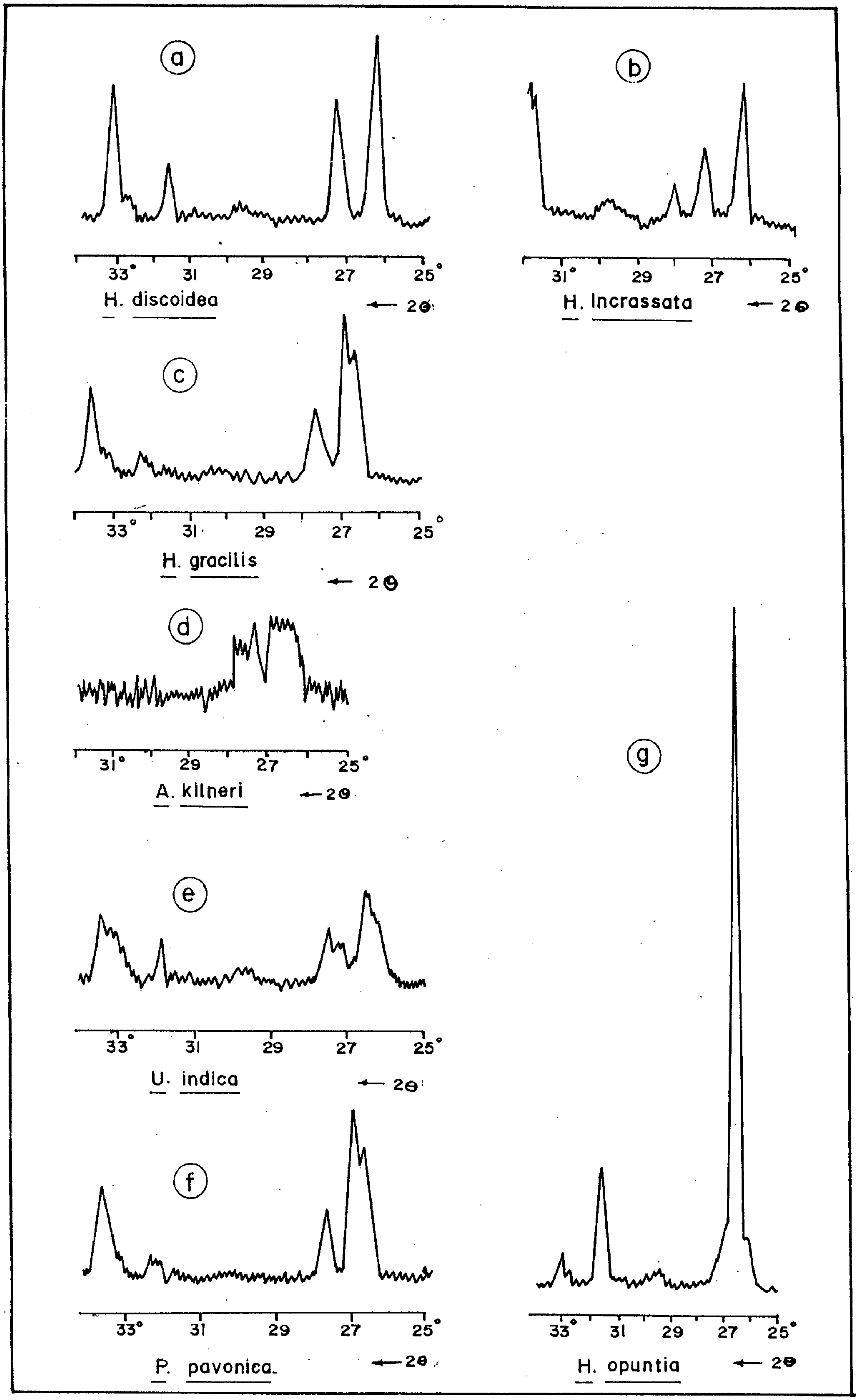


FIG. 27. MINERAL DEPOSITS IN HALIMEDA, ACETABULARIA, UDOTEA AND PADINA SPP.

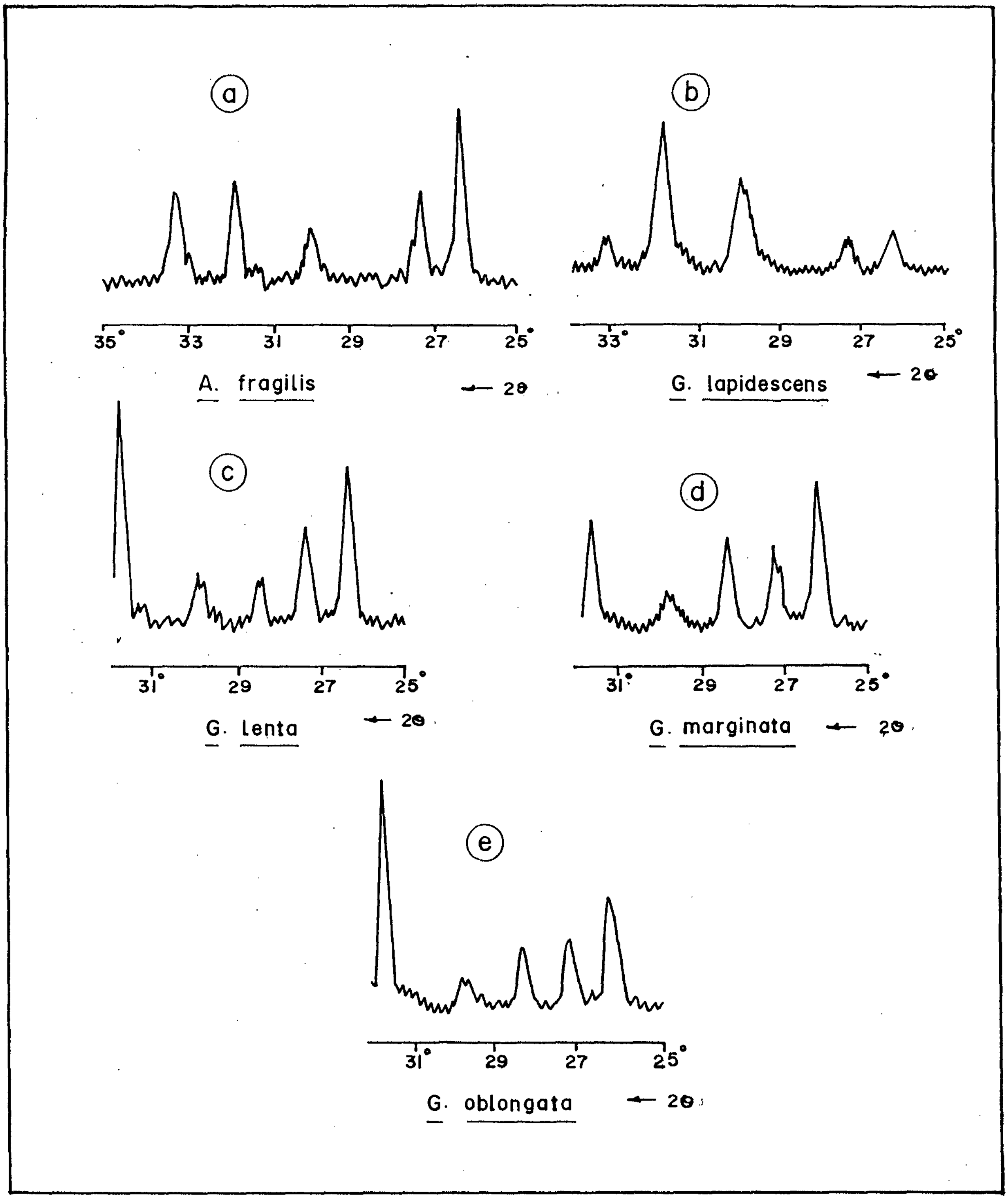


FIG. 28. MINERAL DEPOSITS IN ACTINOTRICHIA AND GALAXAURA SPP.

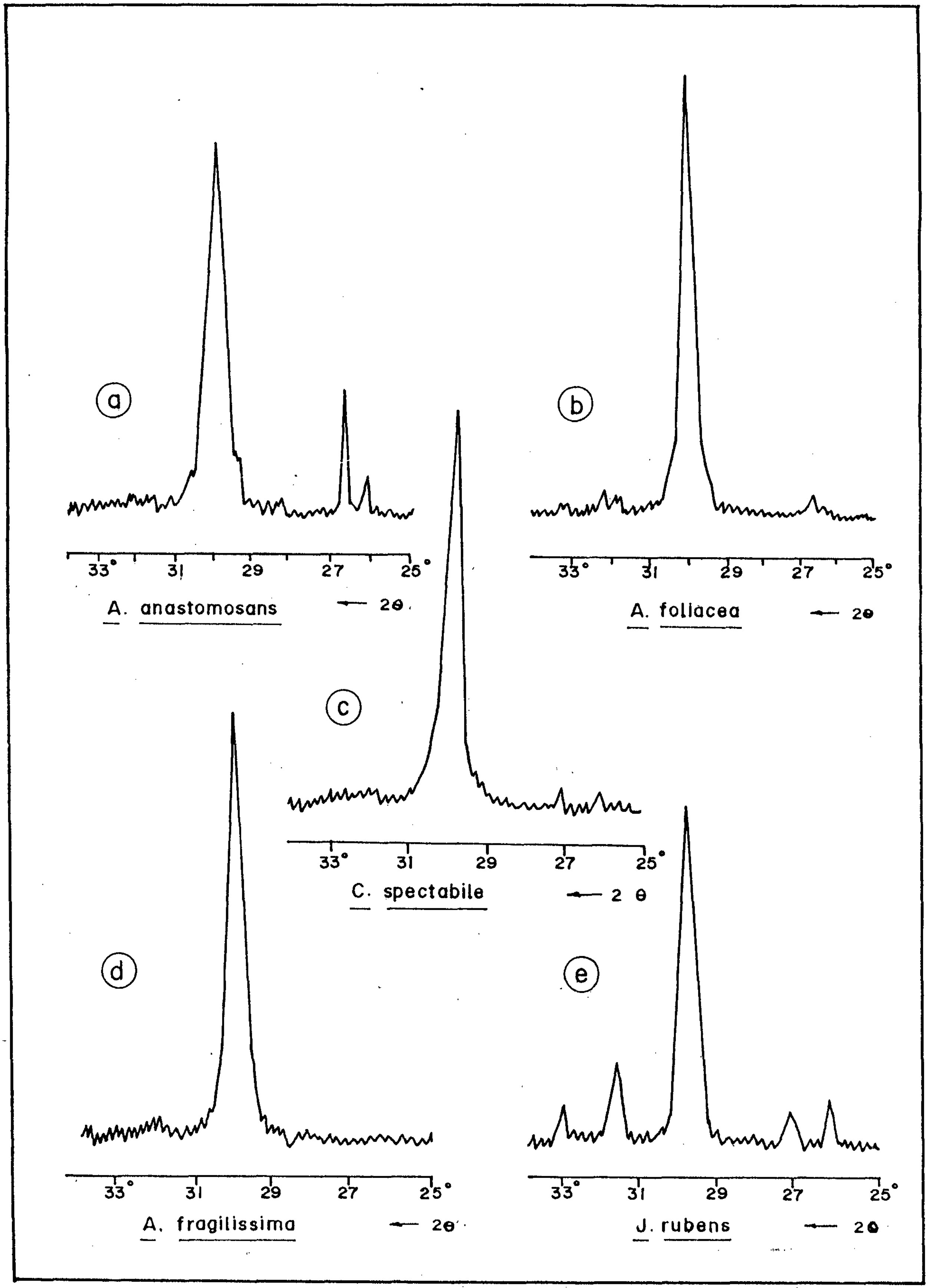


FIG. 29. MINERAL DEPOSITS IN AMPHIROA, JANIA AND CHEILOSPORUM SPP.

Neomeris annulata and N. van-Bosseae showed typical aragonite needles. Mature needles are of Ø.3-Ø.6 um wide and 5-6 um long (Plate VII f,h).

In both the species orientation of crystals was observed to be random . In younger parts of the thallus, crystals were found around the walls of sporangia (Plate VII g) but in older parts of the thallus intercellular spaces become filled with crystals.

2. Phaeophyta

Deposits in Padina pavonica showed aragonitic needles which are about 2-4 um long and Ø.3 -Ø.4 um wide (Plate VII i).

Orientation of the crystals was random. In the oldest part of the thallus crystalline deposits were observed to lose their needle like appearance (Plate VII j).

3. Rhodophyta

General surfaces of Intergenicula of articulated corallines

Intergenicular surfaces of Amphiroa anastomosans, A. anceps A. foliacea, A. fragilissima, Arthrocardia capensis, Cheilosporum spectabile, Jania rubens (Plate VIII a to g respectively). When viewed under SEM, they revealed two distinctive surface morphologies. Except Jania rubens all other species showed 'C' type of surface morphologies while, J. rubens showed 'J' type of surface morphological features.

In the species of Amphiroa, Arthrocardia, Cheilosporum (i.e. species showing 'C' type of surface morphology) cell outlines were observed to vary from round to irregular and also the bases of trichocytes were roundish. (Plate VIII a, d, e, g). Conspicuous concavities were observed in these species because of

PLATE VII

urface morphologies of *Halimeda*, *Udotea*, *Neomeris* and adina spp.

a) Aragonitic needles of *Halimeda tuna*

b) *Halimeda* T.S. - showing calcification in the intercellular spaces

c) Aragonitic needles of *Halimeda simulans*

d, e) Bundles of Aragonitic needles of *Udotea indica* and *U. flabellum*.

f) Aragonitic needles of *Neomeris annulata*

g) Calcium deposition around the walls of sporangia

h) Aragonitic needles of *Neomeris van-Bosseae*

i) Aragonitic needles of *Padina pavonica*

j) Aragonite crystals losing their needle shaped appearance at maturity in case of *Padina pavonica*

PLATE VII

the well developed lateral walls of epithallial cells (Plate VIII a to g). In A. anastomosans trichocytes were abundant compared to A. fragilissima and A. foliacea. Trichocytes were observed to be scattered randomly and quite conspicuous in case of A. anastomosans and A. fragilissima. Trichocytes in all these species showed a slightly raised doughnut shaped base, with a pore lacking a flange and appeared slightly smaller than the surrounding concavities. In case of A. foliacea they appeared to be additional cells produced at the juncture of other cells (Plate VIII c).

Amphiroa anceps and Arthrocardia capensis showed an absence of trichocytes (Plate VIII b, f).

Cells of reproductive region were observed to be smaller compared to the vegetative region in A. fragilissima (Plate VIII d).

In case of Jania rubens regular rows of depression and a terminal ridge around the distal and proximal ends adjacent to the contiguous genicula was observed (Plate VIII h). While in spp. of Amphiroa, Arthrocardia capensis, Cheilosporum spectabile, no clear termination of surface features next to the adjoining walls was observed.

Trichocytes in J. rubens showed a raised wall perforated by a single pore with an expanded flange and trichocyte bases could be easily distinguished from the surrounding epithallial cells (Plate VIII h).

Summary of the results of SEM study of articulated corallines is listed in Table 9.

Table 9 List of the articulated corallines examined with SEM summary of the results

+ = Trichocytes found; - = Trichocytes not found

C = Corallina types; J = Jania types

Taxon	Surface morphology	Trichocytes
Family : Corallinaceae		
Sub. Fly. : Corallinoideae		
Tribe : Corallineae		
Amphiroa anastomosans	C	C+
A. anceps	C	-
A. foliacea	C	C+
A. fragilissima	C	C+
Arthrocardia capensis	C	-
Cheilosporum spectabile	C	C+
Tribe : Janiae		
Jania rubens	J	J+

PLATE VIII

a) Surface morphology of *Amphiroa anastomosans* W.V. Bosse

b) Surface morphology of *A. anceps* (Lamk.) Decaisne

c) Surface morphology of *A. fragilissima* (L.) Lamk. bearing tetrasporic conceptacles (showing small reproductive cells compared to the vegetative cells)

d) 'C' enlarged.

e) Surface morphology of *Amphiroa foliacea* Lamour

f) Surface morphology of *Arthrocardia capensis* Areschoug

g) Surface morphology of *Cheilosporum spectabile* Harvey

h) Surface morphology of *Jania rubens* (L.) Lamk.

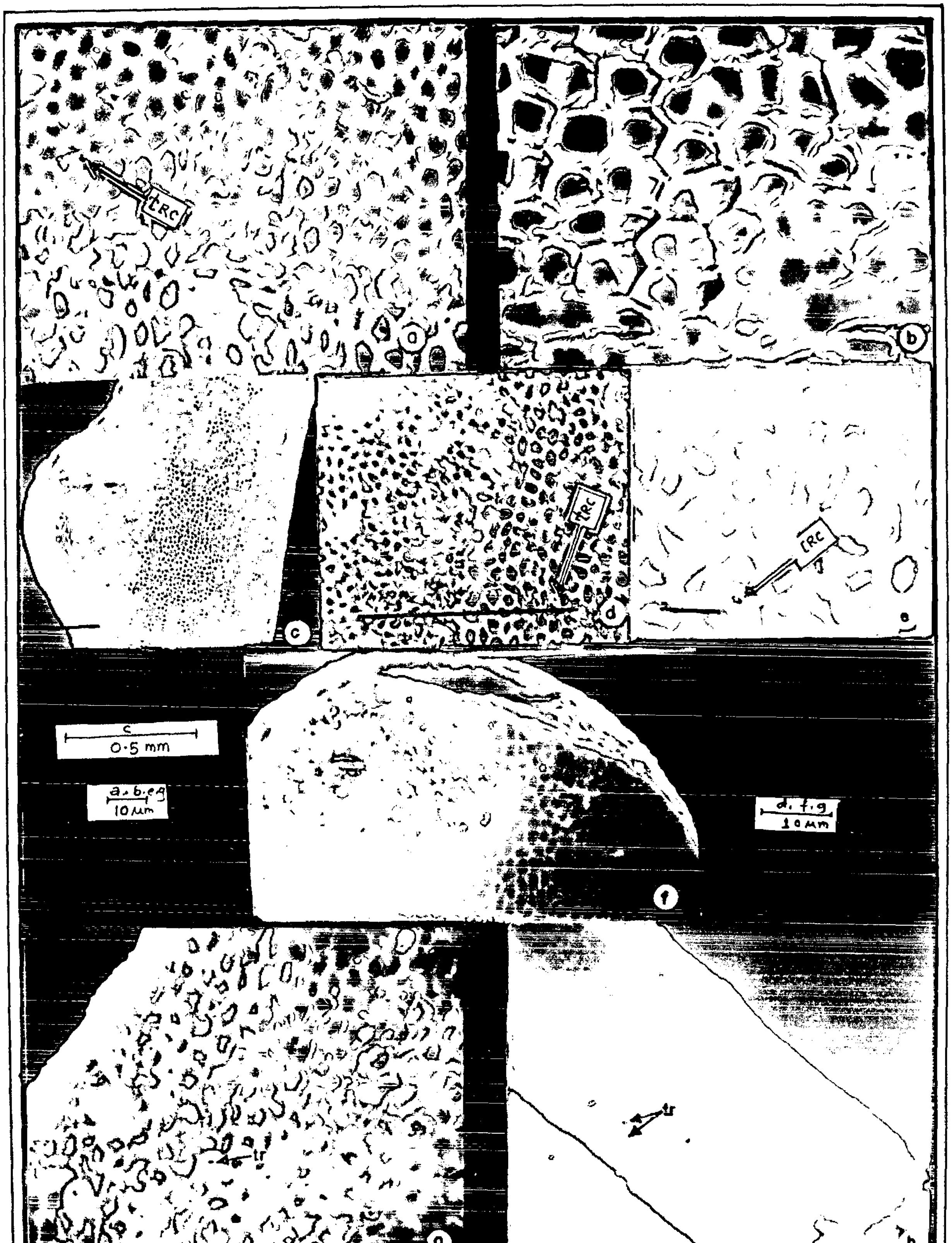


PLATE VIII

IV. DISCUSSION

All Halimeda species (Chlorophyta-Udoteacea) i.e. H. gracilis, H. incrassata, H. opuntia were observed to produce diffraction patterns which were essentially attributable to 'aragonite'. Aragonite needles in the genera Penicillus, Rhipocephalus, Udotea, Tydemania are reported by Lowenstam (1955), McConnell and Hillis (1967) studied aragonitic deposition in H. monile and H. tuna. The mineralization in Udotea indica was also found to be aragonitic. So based on the results and on studies by Lowenstam, (1955) McConnell and Hillis (1967), it can be concluded that aragonite is the predominant mineral deposit of Udoteaceaen members.

Acetabularia kilneri (Chlorophyta-Dasycladales), which is reported here for the first time from India was also observed to deposit aragonite. Present result is in agreement with Vinogradov (1953), Levy and Strauss (1960) and Borowitzka (1982) who studied the aragonitic deposition in Dasycladales.

Padina, the only calcified Phaeophycean form (Dictyotaceae) is reported to deposit aragonite (Levy and Strauss, 1960). P. pavonica was also observed to deposit aragonite confirming the observations of Levy and Strauss (1960).

Galaxaura species, i.e. G. lapidescens, G. lenta, G. marginata, G. oblongata and Actinotrichia fragilis (Rhodophyceae-Nemaliales) showed aragonite as the predominant deposit which is in agreement with Lowenstram (1955), Borowitzka (1982). High magnesium calcite was observed to be the predominant mineral deposit in all the members of family Corallinaceae i.e. in species of Amphiroa, Jania, Cheilosporum, Arthrocardia, confirming with Vinogradov (1953), Borowitzka et. al. (1974), Borowitzka (1982). Johansen (1974) proved that high ambient temperature of the surrounding medium facilitates the incorporation of magnesium in the cell wall. Being a tropical region water temperature is comparatively higher which might be the possible reason for the deposition of high magnesium calcite in these forms. Other minerals like quartz, halite, illite and feldspar were also found to be present in almost all the forms which are possibly related to the contamination from detritus, seawater or organisms growing on or in the specimen.

As far as the surface morphological features are concerned, all species of Halimeda deposit aragonitic calcium carbonate outside the cell wall, in the intercellular spaces. These intercellular spaces are completely isolated from the external seawater by the outer layer of closely appressed utricles. The aragonitic needles completely fill the intercellular spaces of this segment. Wilbur (1969) reported that in H. monile, the needle like crystals form in the fibrous material of the filament wall when the segments are of 36-48 hours old. Crystal formation seems to coincide with the development of chloroplast formation and with the fusion of the outer layer of filaments which isolates the intercellular space from the outside (Marszalek, 1971; Borowitzka et. al., 1974). According to Borowitzka (1982), the process of calcification in the genus Halimeda may be a purely physical mechanism resulting from a combination of anatomical and physiological properties of this alga. According to him, intercellular space which is separated from the external seawater medium by a layer of appressed utricles, causes a long diffusion path for ions from the seawater to the intercellular space where the calcification takes place.

As far as, Neomeris annulata and N. van-Bossae are concerned, there is a layer of appressed outer cells, separating the intercellular space from the external medium which indicates the absence of definite outer cell layer. In U. indica, filaments are interwoven closely and so help in reducing water movement creating a long diffusion path required for the production of pH changes and hence stimulating $CaCO_3$ precipitation. The aragonitic needles are arranged in bundles, and in layers parallel to the axis of filament, which are enclosed within a sheath. According to Marszaleks (1971) and Böhm et. al. (1978), sheath may be playing direct role in calcification by providing an organic matrix for epitaxial nucleation. It is also known to play a role in orienting aragonitic needles.

According to Friedman and Roth (1972), Turner and Friedman (1974) and Böhm et. al. (1978) vacuolar inclusions of calcium oxalate must be supplementing this process.

Corallinacean forms deposit calcite high in magnesium content (Milliman, 1974). Calcite crystals get deposited among the fibrils of cell wall and these crystals show some organization. (Borowitzka and Vesk, 1978). According to Bass-Becking and Galliher (1931), Borowitzka et. al. (1974), these crystals immediately next to the cell have long axis at right angles to the cell, and near the middle lamella, orientation of these crystals is more or less along the axis of growth. Garbary and Johansen (1982) have shown that crystal organization in the Corallinacean cells can be of great taxonomic potential.

Johansen and Silva (1978) suggested two tribes i.e. 'Janiae' and 'Corallineae' of sub family Corallinoideae (Fly-Corallinaceae). Studies by Garbary and Johansen (1982) showed the vegetative distinction between Janiae and Corallinaeae. Corallina-type surfaces occur with several modifications in all genera of the Corallinaeae while Jania-type surface characters are limited to tribe Janiae (Garbary, 1978, Garbary et. al., 1981) . As far as our results are concerned, all the species of Amphiroa, Cheilosporum, Arthrocardia showed C-type of surface morphology while Jania rubens showed J-type of surface morphologies. All C-type surface cells were characterised by round to irregular cell outlines and with round trichocyte bases. All of them excluding Amphiroa anceps and Arthrocardia capensis showed the presence of trichocytes, which should be considered as an additional taxonomic character. Trichocytes i.e. cell and cell complexes produce a single hair was so far reported in Jania rubens and in some crustose coralline forms. (Cabioach, 1971; Johansen, 1980). To the best of our knowledge except for Yamadea (Garbary et. al., 1981), Jania and Haliptilon (Garbary and Johansen, 1982) trichocytes have not been reported in other genera of Corallinoideae. J-type of surface morphology was observed in Jania rubens. Our results also showed that C-type of surface morphological features were observed in the members of tribe Corallineae and J-type of surface feature in tribe Janiae.

CHAPTER 5

ECOLOGY OF CALCIFIED ALGAE ALONG ANJUNA, GOA

I. INTRODUCTION

Marine algae interact with other marine organisms and with their physico-chemical and biological environment. The important factors affecting seaweeds are light, salinity, temperature, water motion and nutrient availability. Among the biological interactions, relation between seaweeds and their epiphytic flora and fauna; interactions between herbivores and plants and the roles of herbivorous predators are very significant (Lobban, et. al., 1985).

A survey of the references indicate that no information available on calcified algae has been combined and reviewed in a single work with a few exceptions like Johansen (1974); Hillis (1980), etc. Adey's studies (1970, b) have resulted in a great deal of structural and ecological information on crustose corallines. Littler (1972), emphasized the structure, reproduction and physiology of calcified forms. Johansen (1974), attempted to present a condensed synthesis of recent work on articulate corallines in perspective with earlier studies. Ecological and physiological studies on calcified algae have begun to appear (Pearse, 1972; Hillis, 1980). But still there is a great potential for this kind of work.

Various estimates and inventories of marine algae of India have been prepared earlier (Boergesen, 1935; Untawale et. al., 1979; Chauhan and Mairh, 1978). Marine algal flora of the Central West Coast of India is studied from ecological point of view by various workers (Dixit, 1940; Dhargalkar, 1981, Agadi, 1986; Untawale et. al., 1989).

In this chapter, an attempt is made to study the distribution, biomass, floral and faunal association of calcified algae, variation in their calcium and magnesium content to assess the effects of some ecological factors of the marine environment over the calcified algae along the Anjuna (Goa) coast.

II. MATERIALS AND METHODS

A) Study area :

Anjuna, Goa (Lat. 14 49'E to 15 52'N & Long. 13 18' to 74 24'E) has a sandy stretch covering 2.5 km and rocky boulders covering 1.4 km area (Fig. 30). It has a wide intertidal expanse. The shore is densely covered, moderate sized boulders of granite and laterite providing numerous sheltering areas (Plate IX a).

Climatologically this region shows three seasons, premonsoon (March-May), monsoon (June-September) and postmonsoon (October-February). Annual average rainfall is 3000 mm. Along the coast the tides are of mixed type with unequal heights of low and high levels. The mean tidal level is 1.74 m at spring and 0.3 m at neap. The impact of wave action is moderate to strong.

B. Environmental parameters :

Seawater samples were analysed for dissolved oxygen, nutrients (PO_4-P, NO_3-N, NO_2-N) and salinity using standard methods (Strickland and Parsons, 1972). For the analysis of pH, few drops of chloroform were added to seawater as a preservative. Surface water temperature was also measured at the time of collection.

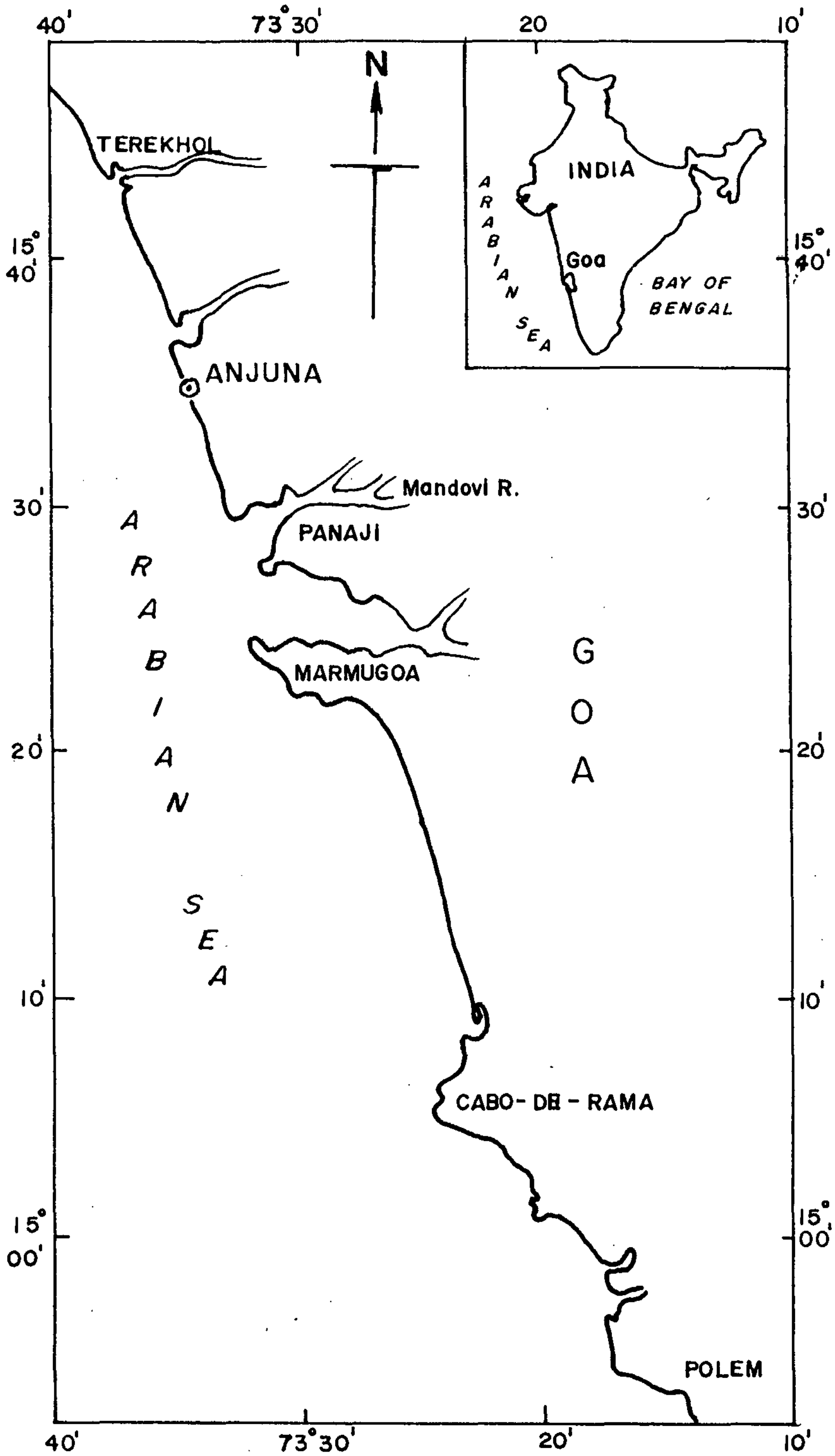


Fig. 30 Map of Goa coast showing the station studied.

C. Biomass :

Monthly samples for biomass were taken placing a 0.25 m^2 quadrant randomly at different levels in the intertidal region during January to December 1987. Algal samples were cleaned first with seawater and then with fresh water and wet weight per unit area was determined for *Amphiroa fragilissima*, *Cheilosporum spectabile* and *Padina gymnospora*.

D. Faunal and floral association :

To study the fauna associated with calcified algae, samples of *Amphiroa fragilissima*, *Cheilosporum spectabile*, *Jania rubens*, and *Padina gymnospora* were collected randomly and were fixed in 10% seawater formalin. Associated animals were sorted out and identified.

In a similar way, floral association was studied.

E) Epithallial shedding :

SEM method (see Chapter 4).

F) Estimation of calcium and magnesium :

Algal samples were handpicked from the intertidal region and were washed first with seawater and then with fresh water and finally with double distilled water. Samples were first dried in the air and then in the oven at 50 C. A known amount of algal powder was digested in concentrated HNO_3 and $HClO_4$ and finally with concentrated HCl. Digestion was continued till the white residue was obtained. The residue was dissolved by adding known volume of double glass distilled water, and the clear residue free solution was used for the estimation of calcium and magnesium by Atomic Absorption Spectrophotometry. The standards and blanks were also treated in the same way as above. Analysis were made in duplicate and average values are represented on the basis of percentage dry weight.

III. RESULTS

A) Environmental parameters : A seasonal cycle was observed in the environmental parameters of nearshore waters along Anjuna coast (Fig. 31). There was a decrease in the values of dissolved oxygen from May to August with an increase till December, while dissolved oxygen registered higher values during May to August. pH did not show much variation. Salinity decreased from May to June and showed a gradual increase upto November. NO_3-N showed higher values in June and registered a gradual increase upto November, where as PO_4-P increased in July and October. No regularity was observed in NO_2-N values.

B) Distribution of calcified algae : *Amphiroa fragilissima*, *Cheilosporum spectabile*, *Jania rubens* and *Padina gymnospora* were the only calcified algae observed growing along this coast. No Chlorophycean calcified alga was observed in this area. During the period of investigation, these algae showed spatial and seasonal distribution. As far as the spatial distribution is concerned, *C. spectabile* was observed mostly in the wave break zone i.e. in the infralittoral fringe. *A. fragilissima* was observed in the lowest midlittoral zone. These two algae and *J. rubens* were also observed in the shallow rock pools. The growth of *Padina gymnospora* was restricted to the rock pools.

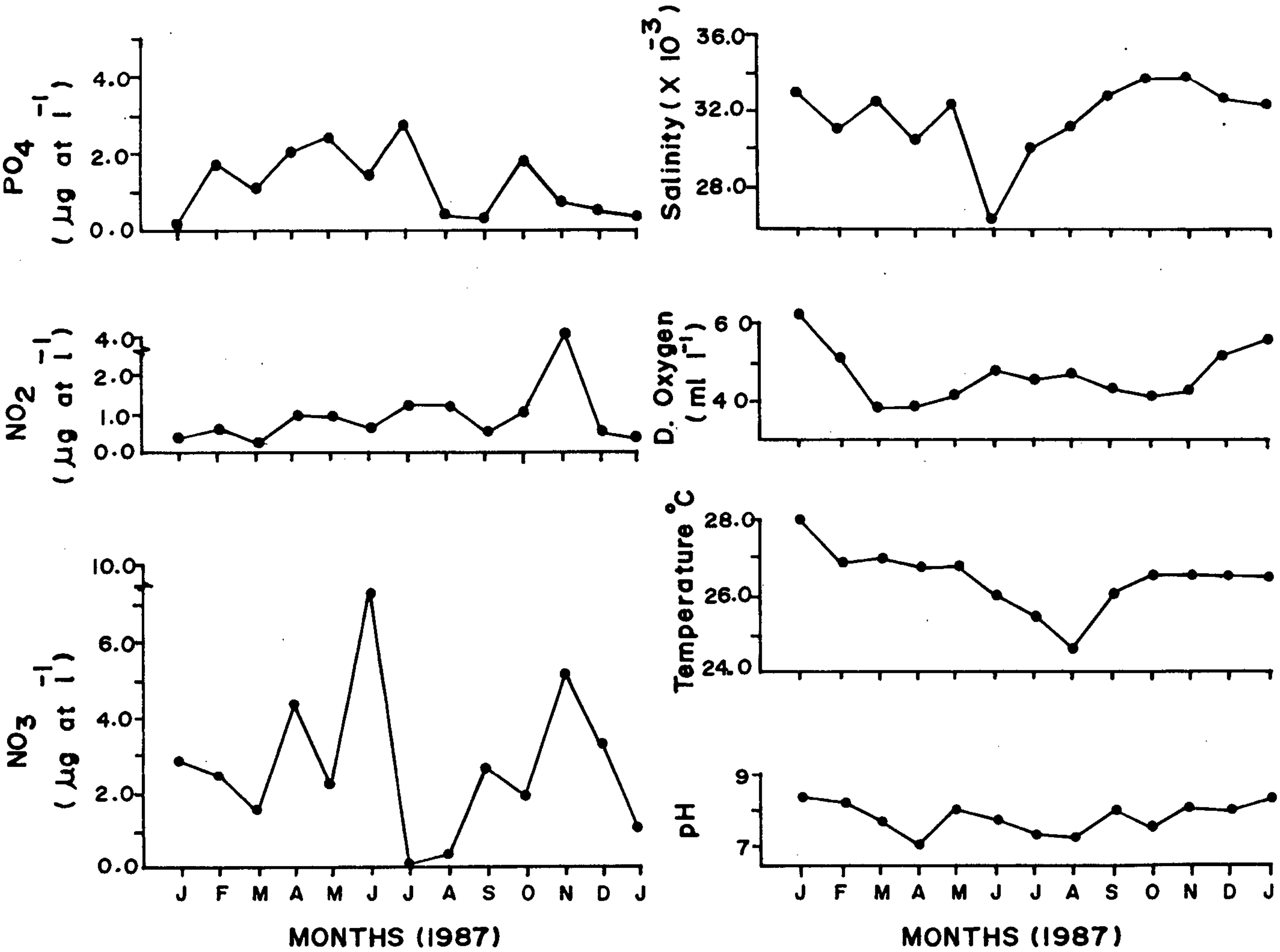


Fig. 31 Environmental data of the station studied along the Goa coast

A. fragilissima, C. spectabile, and J. rubens were observed throughout the year. P. gymnospora showed a distinct seasonality in its occurrence, with a complete disappearance in monsoon season. Distribution of these calcified forms is shown diagrammatically in Fig. 32 and their seasonal distribution is represented in Table 10.

Spatial distribution of Padina gymnospora and Cheilosporum spectabile is shown in Plate IX b, c.

C) Faunal and floral associations

Faunal associations : Fauna associated with articulated corallines included polychaetes, gastropods, pelecypods, nematodes, etc. Also included were the brittle stars and brachyurian crabs (Plate XI, a-e). Among Polychaetes, nereids were the most common. Pelecypod fauna was exclusively dominated by brown mussel spat, the Modiolus metcalfei. Common representatives of gastropods were Turbo sp., Pyrene sp., Trochus sp.

The associated fauna of Amphiroa fragilissima and Cheilosporum spectabile was more or less common except for the association of Gemmaria (a Zoanthoid) with Amphiroa fragilissima (Plate X a).

Floral associations :

Ulva fasciata, Gelidium pusillum, Chaetomorpha media, Sargassum cinerimum, Gelidiopsis variabilis were observed in the vicinity of Cheilosporum spectabile (Plate X b). While A. fragilissima and Jania rubens were observed growing in the vicinity of Stoechospermum marginatum and Dilophus fasciola.

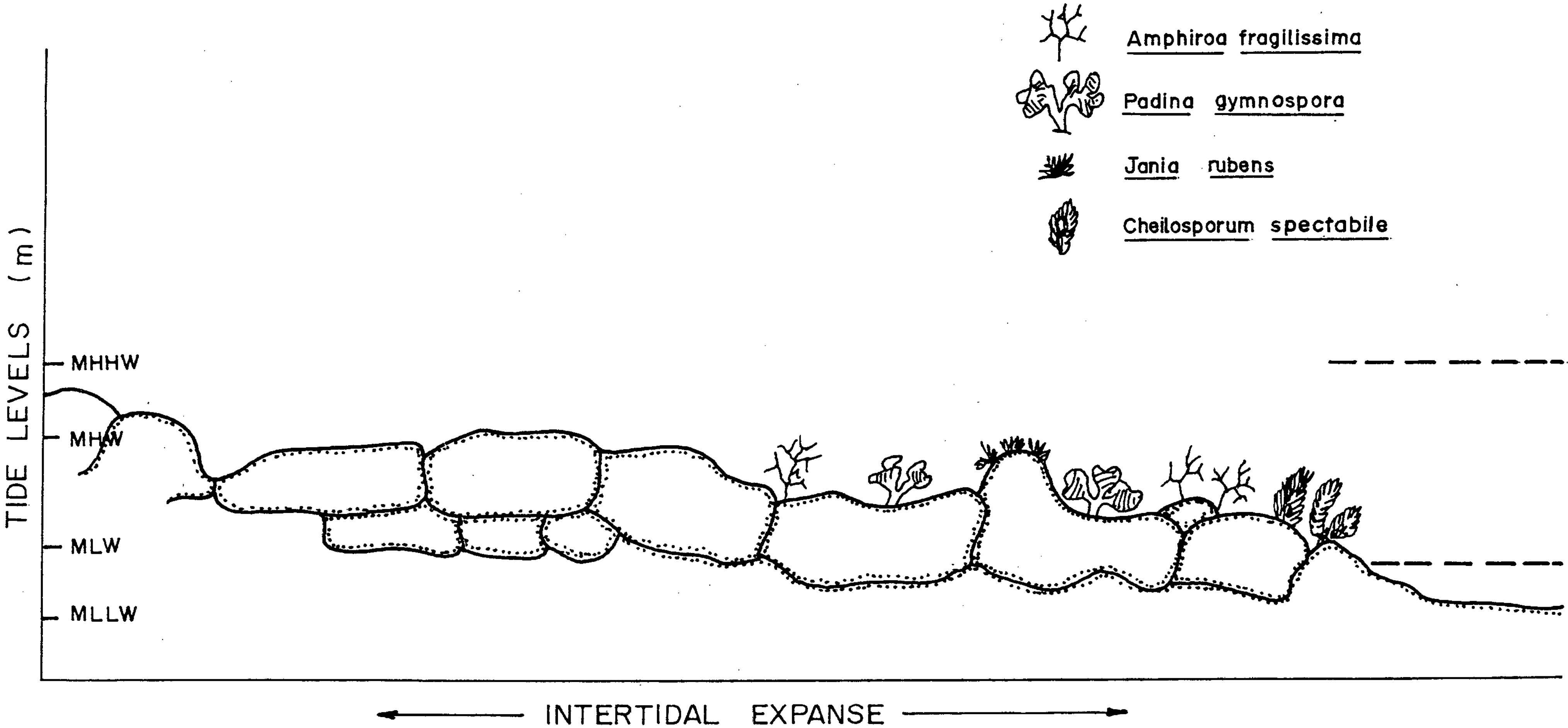


Fig. 32 Shore profile of Anjuna showing the distribution of calcified algae.

Table 10 Seasonal distribution of calcified algae along Anjuna, Goa

+ = recorded ; - = not recorded

Alga	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
A. fragilissima	+	+	+	+	+	+	+	+	+	+	+	+
C. spectabile	+	+	+	+	+	+	+	+	+	+	+	+
J. rubens	+	+	+	+	+	+	+	+	+	+	+	+
P. gymnospora	+	+	+	+	+	-	-	-	-	+	+	+

PLATE IX

Study site of Anjuna, Goa; habitat of *Padina gymnospora* and *Cheilosporum spectabile*

Ⓐ Study site of Anjuna, Goa. →

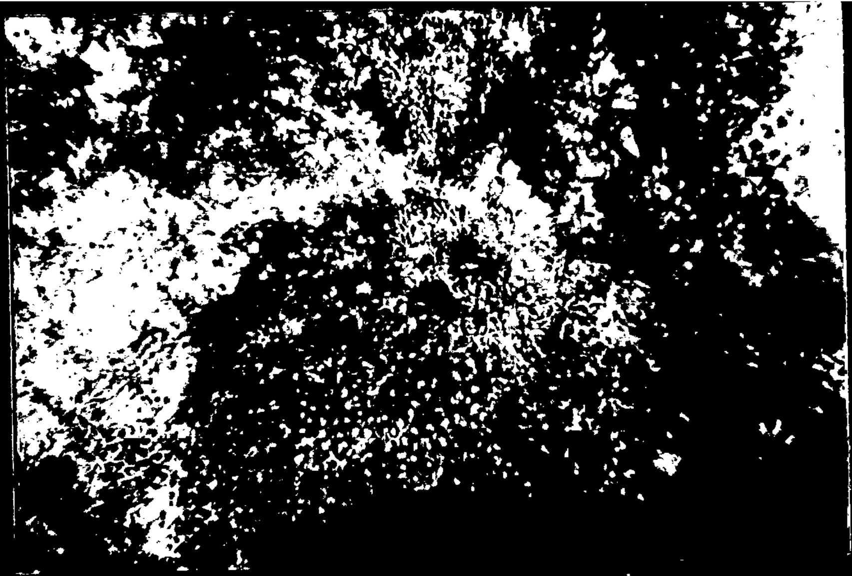
Ⓑ Habitat of P. gymnospora. ←

Ⓒ Habitat of C. spectabile. →

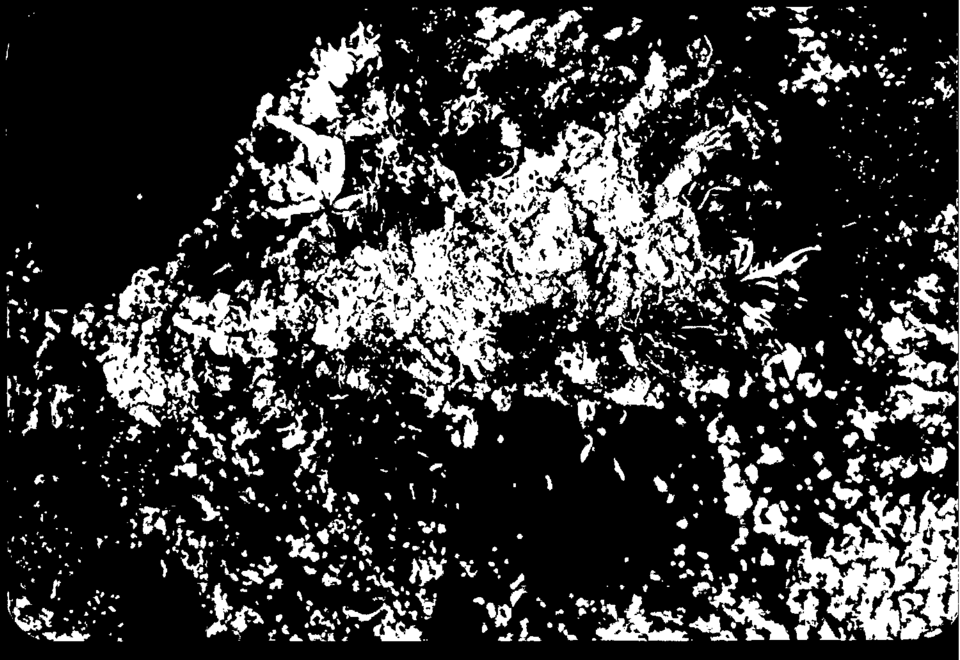
PLATE IX

PLATE X

Floral and faunal associations of calcified algae.



(a) Association of *A. fragilissima* and *Gemmaria*



(b) *Cheilosporum spectabile* and its associated flora.

PLATE X

Fosliella farinosa was observed to be growing epiphytically on *P. gymnospora*. Young intergenicular areas of articulated corallines were noted to be surprisingly clean but, crevices formed in the genicular areas supported microscopic algae like diatoms and filamentous algae like *Acrochaetium* sp. *Ceramium rubrum* and *Centroceras clavulatum*, etc.

D) Epithallial shedding : Weakly calcified epithallial layer was observed to be sloughing off in case of *Amphiroa fragilissima* (Plate XI, f).

E) Biomass : The monthly biomass values for *A. fragilissima*, *C. spectabile* and *P. gymnospora* are shown in Fig. 33. Maximum and minimum values for *A. fragilissima* and *C. spectabile* were estimated in May and August respectively. For *P. gymnospora* maximum and minimum values were estimated in January and May respectively.

F) Variation in the Ca, Mg contents : Variation in the calcium, magnesium contents in *A. fragilissima*, *C. spectabile*, *J. rubens* and *P. gymnospora* is shown in Table 11.

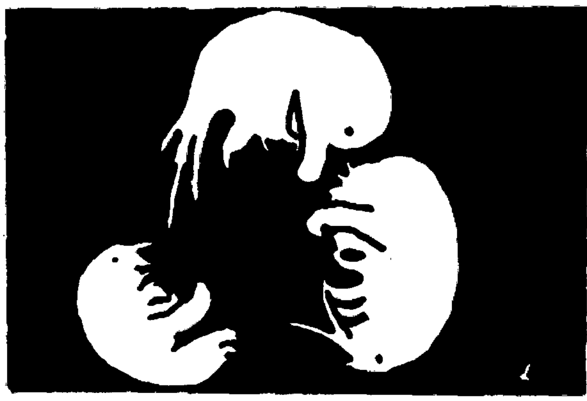
Maximum and minimum values for calcium and magnesium contents in *A. fragilissima* were estimated in May and September respectively and for *C. spectabile* in May and July. In case of *J. rubens* peak values were observed in May whereas minimum were in September. Ca, Mg contents in *P. gymnospora* showed maximum and minimum values in May and January respectively.

PLATE XI

Associated fauna of calcified algae and Epithallial shedding

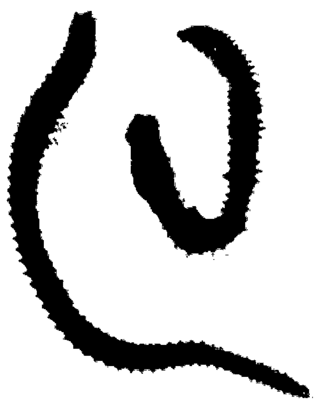
Brachyurian crabs

Modiolus metcalfei



Amphipods

Brittle stars



Polychaetes

Epithallial shedding

PLATE XI

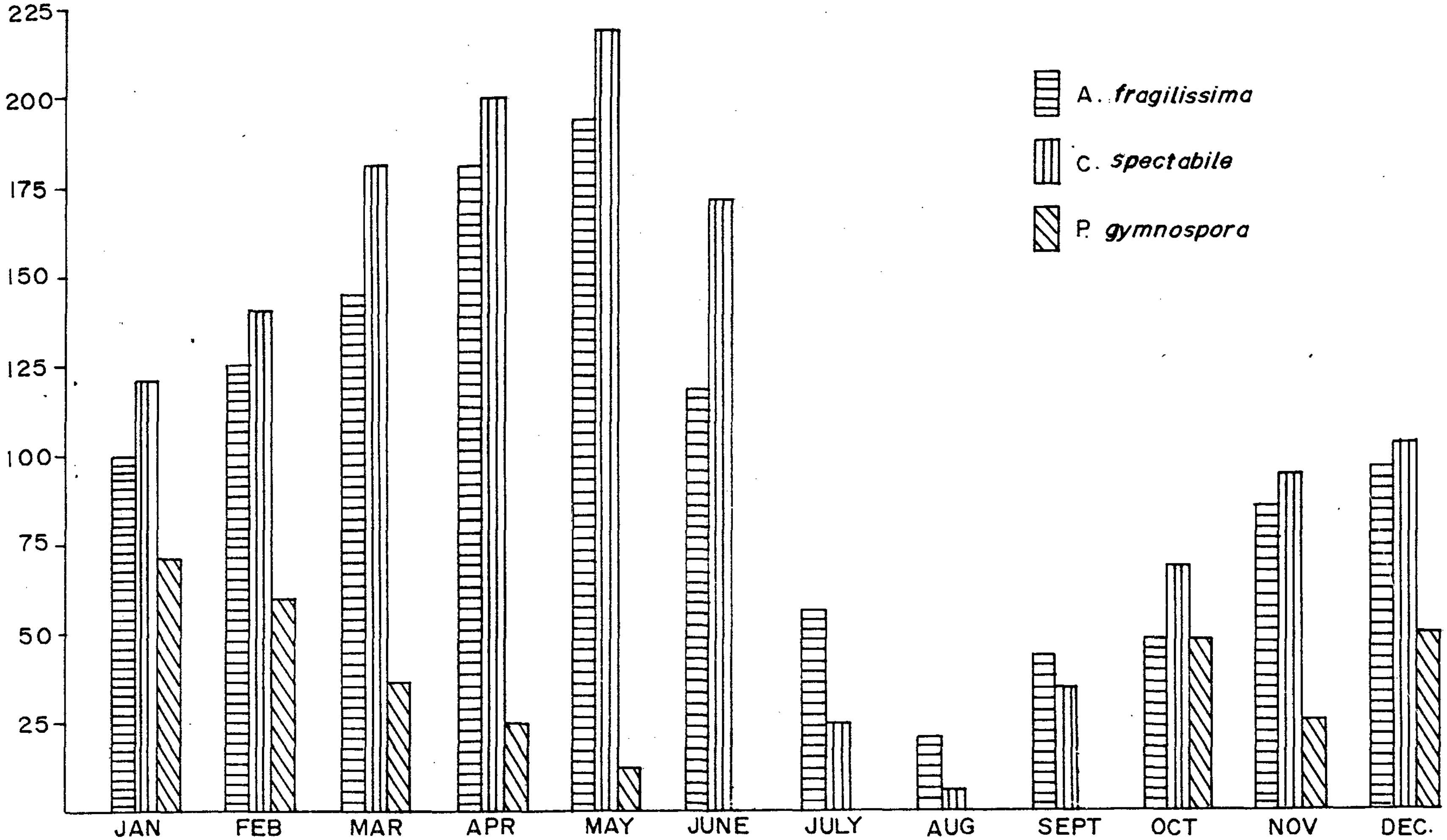


Fig.33 Monthly variation in biomass at Anjuna (Goa).

Table 11 Variation in Ca, Mg contents in calcified algae along Anjuna coast (Goa)

MONTHS	*A. fragilissima*		*C. spectabile*		*J. rubens*		*P. gymnospora*	
	Ca %	Mg %	Ca %	Mg %	Ca %	Mg %	Ca %	Mg %
JAN	55.90	10.57	52.18	11.91	49.91	10.92	13.40	07.23
FEB	55.98	10.99	53.59	12.03	50.90	10.97	14.31	08.74
MAR	57.18	11.22	63.63	12.08	52.95	11.45	17.77	10.83
APR	58.86	12.59	69.18	13.18	54.54	11.57	21.31	09.83
MAY	69.83	14.48	73.18	14.40	60.22	13.55	21.45	09.96
JUN	60.68	12.18	42.95	14.52	47.04	12.04	-	-
JUL	58.73	10.92	41.40	13.15	44.99	11.90	-	-
AUG	43.77	09.55	43.66	12.18	47.95	10.45	-	-
SEP	41.69	09.02	44.01	11.18	36.59	09.78	-	-
OCT	47.85	10.00	46.18	12.06	44.77	09.95	19.09	09.05
NOV	49.06	11.46	48.81	11.95	47.05	10.18	20.22	08.90
DEC	51.84	12.08	50.08	10.53	47.95	10.32	20.15	07.83

DISCUSSION

As mentioned earlier, Amphiroa fragilissima, Cheilosporum spectabile, Jania rubens and Padina gymnospora are the only calcified forms growing along this coast. These forms showed marked seasonal changes in their pattern of distribution viz. complete disappearance of visible thalli in some seasons, P. gymnospora showed complete disappearance in the monsoon season. Although articulated corallines were observed throughout the year, growth was stunted in the months of June to September i.e. these algae remained dormant during this period. According to Underwood (1981), seasonal changes in the patterns of distribution of different algae from October to January could be possible due to seasonal variability of reproduction or recruitment of species.

Spatial distribution of these forms indicates their adaptation to many factors like submergence and emergence of water, wave action, topographical characteristics, etc. As a general rule, articulated corallines inhabit shallower waters than do crustose (Johansen, 1974). Frequent dominance of articulate corallines in areas of heavy surge or surf can be related to their adaptability to bend owing to their jointed nature. These plants often form a dense tuft or cushion, which must be acting as a structural defense and so can minimize the accessibility for grazing (Steneck and Watling, 1982). These algae grow in the wave break zone as the herbivores are known to be less in this area (Littler, 1983). The positive correlation between exposure and abundance of articulated corallines is observed by Evans (1947). Dense growth of articulated corallines, in the surf zone can be related with the supply of nutrients in that area. Splashing of water provides a wetting effect to these forms, thus, saving them from complete desiccation.

Articulated corallines were also observed in the shallow rock pools (although not abundantly). According to Johansen (1974), these algae growing in the shallow pools are able to survive several hours of emergence provided the plants are not in the direct sunlight. So also freedom from epiphytes, and general health of plants in the tide pools appear to decrease in warmer and smaller pools.

Species composition of a community is determined by many biological and environmental factors. Algae provide shelter and food to the micro-organisms and also surface for the settlement of spores or sessile organisms. Densely branched holdfast of the articulated corallines provides shelter to the many organisms. Rhizomatous branching of the holdfast supports a rich fauna. An erect articulated portion of these algae cannot be climbed by limpets. An extensive survey of calorific values of benthic coralline algae were shown to be notably low by Paine and Vadas (1969). According to them, calcareous algae are least preferred by browsing invertebrates. A. fragilissima grows on Gemmaria (Zoanthoid), the water soluble fraction of which exhibited hypotensive activity (Kamat et. al., 1981). The same compound is also derived from A. fragilissima (Solimabi et. al., 1987). Their association might be symbiotic.

Phenomenon of epithallial shedding which is commonly observed in all coralline algae (Suneson, 1982) was also observed in A. fragilissima. Weakly calcified epithallial layer is sloughed off which helps to maintain the surface clean and avoids settlement of microalgae and spores. This layer is replaced by the meristem surviving beneath. The sloughing or removal of uncalcified parts of epithallial strata may explain the paucity of epiphytes.

Furuya, (1960) found that calcium carbonate constitutes 65-70 % of the dry weight of corallines, whereas the magnesium content was considerablly higher than in the non-calcified algae (c.f. Johansen, 1974). The incorporation of magnesium into corallinaceous cell walls is shown by Baas-Becking and Galliher (1931) and Milliman et. al., (1971). Light is known to stimulate the rate of calcification (Goreau, 1963). Vinogradov, (1953) stated that, the species living close to the equator have more magnesium than the forms further away. During this period of study, it was observed that, the maximum calcium and magnesium content was observed in the months of May i.e. in the period of high light intensity while reduction in the calcium and magnesium values was observed in the monsoon season. In this season, there was increase in the phosphate values. Increase in the phosphate values are known to inhibit calcification (Brown et. al., 1977).

From the above account it is difficult to conclude the mechanisms by which the distribution and biomass of calcified algae changes. The substratum, environmental parameters, and bioactive compounds in them may be affecting these changes.

CHAPTER 6

SUMMARY

The present work on calcified algae is based on the forms collected from various localities of India having diverse habitats viz. coastline, oceanic islands and submerged banks. Altogether, 17 genera and 49 species of calcified algae have been collected from these localities, of which, 7 genera and 20 species represent Chlorophyta, 1 genus and 3 species represent Phaeophyta and 9 genera and 26 species represent Rhodophyta. Acetabularia kilneri J. Ag., Neomeris van-Bosseae Howe and Halimeda tuna f. platydisca (Decsne) Boergs are recorded for the first time in India. Calcified flora of Gujarat (west coast), Tamil Nadu (east coast), Lakshadweep and Andamans (oceanic islands) showed similarity. Distribution of calcified algae is observed to be dependent on the submergence and emergence of water, wave action, topographical characteristics of each place and on the nature of substratum. Biotic factor like grazing, also play an important role in the distribution of calcified algae.

14 species of Chlorophyta (9 species of Udoteaceae, 3 species of Dasycladales), 3 species of Padina (Phaeophyta) and 15 species of Rhodophyta (9 species of Nemaliales, 6 species of Cryptonemiales) are described for their vegetative and reproductive features. A classification scheme suggested by Bold & Wynne, (1979) is followed to recognise families and genera whilst for identifying subfamilies and further divisions, classification scheme suggested by Johansen, (1969 a) and Johansen and Silva, (1978) is accepted.

Halimeda tuna f. platydisca, Acetabularia kilneri and Neomeris van-Bosseae are described for their gross morphological features for the first time. Actinotrichia fragilis Forssk. (Chaetangiaceae-Rhodophyta), cystocarpic details of which were not known till to date are described in the present account. It is observed that gonimoblast filaments in the genus Actinotrichia are surrounded by sterile filaments which differ from Galaxaura and resembles other members of the family Chaetangiaceae i.e. Scinaia and Pseudogloiophloea.

Minerological studies show that aragonite is the predominant mineral deposit in genera like, Halimeda, Udotea (Chlorophyta-Udoteaceae), Acetabularia (Chlorophyta-Dasycladaceae), Padina (Pheophyta-Dictyotaceae) and Actinotrichia, Galaxaura (Chaetangiaceae-Rhodophyta). In Corallinaceous forms like Amphiroa, Jania and Cheilosporum, calcite high in magnesium is the predominant mineral deposit. Halite, illite, quartz and feldspar are the major contaminants from detritus, seawater and organisms growing on and in these algae.

In the genus Halimeda, aragonite deposition takes place outside the cell wall, in the intercellular spaces while in Udotea, aragonitic needles get arranged in layers parallel to the axis of filament and within a sheath. In case of Neomeris, crystallization takes place around the walls of sporangia. Definite crystal organization is observed in Corallinaceous genera like Arthrocardia, Amphiroa and Cheilosporum. Cell outlines in these forms vary from round to irregular with roundish trichocyte bases (C-type of surface morphology, characteristic of the tribe Corallineae) while in Jania, regular rows of depression and a terminal ridge around the distal and proximal ends, adjacent to the contiguous genicula is observed. It also shows a raised wall perforated by a single pore, with expanded flanged trichocyte bases, quite distinct from the surrounding epithallial cells (J-type of surface morphology, characteristic of Janiae). Surface morphological features also show additional taxonomic characters like the presence or absence of trichocytes. Amphiroa foliacea, A. fragilissima, A. anastomosans, Cheilosporum spectabile and Jania rubens show the presence of trichocytes while Amphiroa anceps and Arthrocardia capensis indicates the absence of trichocytes.

Ecological studies carried out at Anjuna, Goa showed distinct seasonality in the occurrence of calcified algae. Rhizomatous branching of the holdfast of articulated corallines shelter rich fauna. The phenomenon of epithallial shedding was observed in the articulated alga A. fragilissima, helping it to maintain the surface clean. Associations of A. fragilissima with Gemmaria may be due to the bioactive compound (histamine) present in them. Increase in the phosphate values showed an adverse effect on calcification whereas an increase in the calcium and magnesium contents were proportional to the increase in the temperature.

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RELATED PUBLICATIONS

Flora of Beyt Shankhodar in the Gulf of Kuchchh

UNTAWALE A G AND AMBIYE VIJAYA
National Institute of Oceanography, Goa, India.

Different types of flora of Beyt Shankhodar in the Gulf of Kuchchh have been studied with reference to the abiotic and biotic factors.

Major floral groups were both of terrestrial and marine habitats. Most of the terrestrial plants are of xerophytic nature and scanty due to the extreme climatological conditions. About 33 species of angiosperms have been recorded from this island. Qualitative distribution of the intertidal marine algae of this island indicated 120 spp. belonging to chlorophyta (18 genera - 33 species), Phaeophyta (20 genera - 34 species) and Rhodophyta (43 genera - 54 species). Most common were represented by the genera *Ulva, Codium, Caulerpa, Dictyota, Padina, Stoechospermum, Hypnea* and *Acanthophora.*

Mangrove flora was conspicuously absent perhaps because of the strong current and 'tidal bore'.

INTRODUCTION

Beyt Shankhodhar in the Gulf of Kuchchh is also called as "Beyt Dwarka". As the shape of this island resembles conch shell, which are extensively found along this shore, it is named as "Beyt Shankhodhar". Mythologically it was the summer resort of Lord Shri Krishna. It is 2 km off Port Okha (Gujarat) *(Fig.1)*.

Archaeologically it is proved that the entire part of the Gulf of Kuchchh was almost dry land, 9000 years ago and Dwarka Island must have been connected to the mainland of Okha. This is because of the tidal dominance in the entire Gulf of Kutch. (Rao, 1987: 22-30). As a result of this present Beyt Shankhodhar got separated from the mainland of Okha. A series of drastic ecological changes must have taken place in this process which ultimately resulted in the formation of several islands where now arid climate, scanty rainfall and xerophytic flora prevail.

Several taxonomists have studied the flora of west coast of India (Cooke, 1901-1909, Talbot, 1909-1911), but they neglected the islands. Blatter (1908-1909: 756-77) also studied the flora of Gulf of Kuchchh. Rao *et al* (1964: 31-42; 1966: 16-24) studied ecology of Saurashtra and neighbouring islands for strand flora. Misra (1960: 187-203) studied ecology, distribution and seasonal succession of marine algae of India, where he has discussed the Gulf of Kuchchh region. Chauhan *et al* (1968-1978: 648) surveyed the Saurashtra coast and Gulf of Kuchchh for seaweed resources. Bhanderi and Trivedi (1974: 97-99) have evaluated the algal resources along Hanumandandi and Vumani reef of Beyt Shankhodhar.

These islands are very interesting from the view point of phytogeography and thus show similarity of floristic and faunistic elements, as well as geological structures with adjacent mainland. Present paper deals with the flora of Beyt Shankhodhar and factors affecting the vegetation.

Geomorphology : Beyt Shankhodhar is a narrow strip of sand and rocks and is 13 km long. The east end of Beyt Shankhodhar is composed of sand hills covered by bushes and is called "Hanuman Point". The south eastern point is called as "Padmatirth Point" *(Fig. 2)*. Between the sandy southeast of Beyt Shankhodhar and mainland of Okhamandal the passage is very shallow having bank in the mid-channel which is nearly dry during low tides (Gujarat Gazetteer 1970: 634).

Geology : The substratum is composed of miliolite and called as "Porbandar stone" (Ahmed, 1972: 222). It is covered with silt, sand and clay.

Climate : The climate of this area is arid to semi-arid. Climatological data from meterological observations at Dwarka show total annual rainfall ranging from 100-220 mm. Maximum temperature varies from 35 ° - 38°C. Minimum temperature ranges from 15 ° - 20° C. The extreme temperatures show ± 5° C fluctuations. Average wind velocity is 17.1 knots/hr. Relative humidity is maximum during monsoon, and varies from 70-80%. Tidal amplitude (also called as Tidal-bore) varies from 6-7 meters. Tide increase in the velocity near Beyt from 2-3 knots to 3-4 knots/hr at Dwarka.

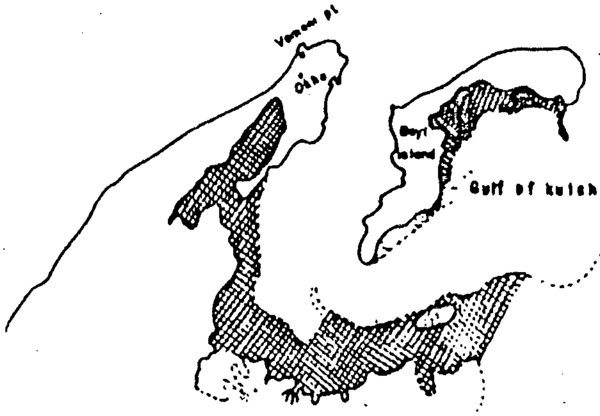

Fig. 1 Beyt Shankhodhar in the Gulf of Kutch

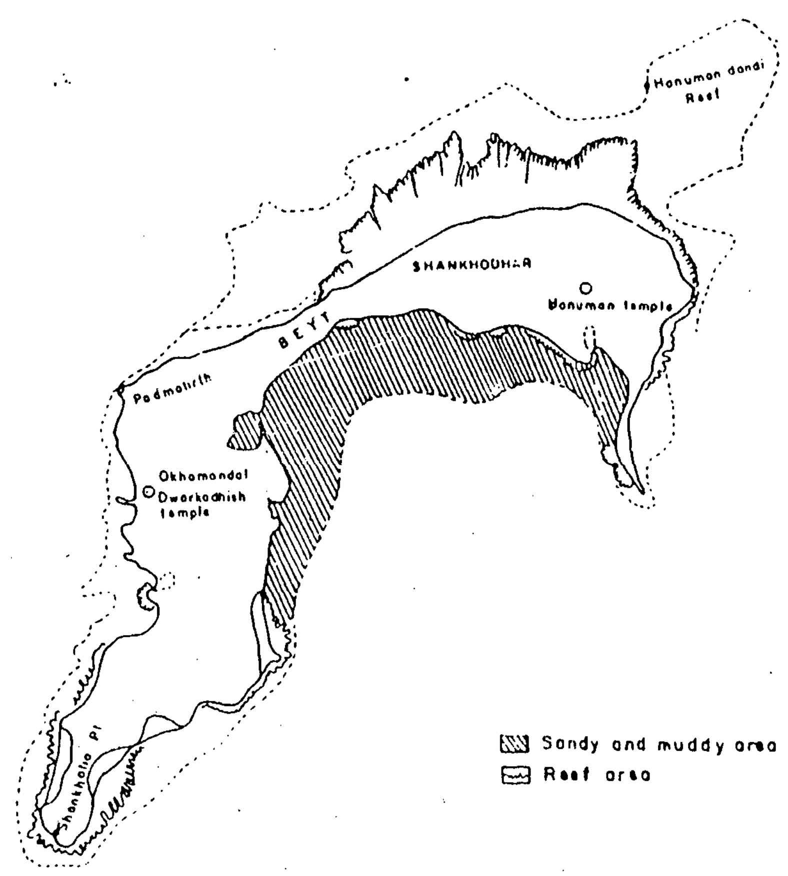

Fig. 2 Beyt Shankhodhar

Vegetation : The entire flora of Beyt Shankhodhar can be classified into two major groups:
1. Terrestrial flora
2. Intertidal flora

1. *Terrestrial flora :* It is composed of herbs, trees and shrubs inhabiting the central region of this island. Altogether 33 plants belonging to 21 families have been collected from this area. This can be subdivided into (a) *land plants* (b) *sand dunes*.

a. Land plants : It is mainly composed of dry, deciduous, thorny shruby plants. Trees are rarely seen. Unsatisfactory growth of trees is due to indiscriminate grazing and cutting. *Caryota urens, Acasia catechu, Zizyphus* spp. are very commonly seen in this island. Herbal flora includes *Boerahaavia diffusa, Achyranthus aspera, Launea pinnatifida, Sanchus* sp., *Cyperus aranarius, Coldenia procumbens, Trichodesma indicum, Cressa critica, Capparis aphylla, Thevetia nerrifolia, Calotropis giganta, Hemidesmus indicus, Suaeda maritima* are common shrubs.

b. *Sand dunes :* These sand dunes show the presence of formation of psammophytic vegetation, mostly of herbaceous spp. These plants have ability to bind sand, rapid regeneration, and reproduction. They can also tolerate high temperatures and low water requirements. *Ipomea pes-caprae, Launea pinnatifida, Spinifex squarrosus* and several other grasses and sedges are the common sand dune plains on this island. Along with these dunes *Cyperus aranerios, Portulaca* sp., *Periploca aphylla, Prosopis spicigera* are found in association.

2. *Intertidal flora :* The marine flora is represented by several species of a) *marine algae* and b) *seagrasses*. It shows complete absence of mangroves.

a. *Seagrasses :* Very few plants of *Halophila ovalis, Cymmodocea rotundata* are observed mostly in the region where the substratum is covered with the silt.

b. *Marine algae :* The growth of marine algae is dependent on various factor like tides, wave action, nature of substratum, salinity and nutrients. Marine algal flora of Beyt Shankhodhar is remarkably rich and supported by gently sloping littoral region, with extensive flat areas, rock pools and puddles. Similarly, the dead coralline substratum also provides very good substratum.

The marine algal zonations according to the tidal positions at Beyt Shankhodhar are discussed below :

i) *Supra littoral zone :* This belt is recognised as blackish green belt on sandy soil substratum. *Lyngbya majescula, Phormidium* sp. and *Calothrix* sp. are important members of this belt.

The shallow pools of this belt show association of *Laurencia, Chondria, Ectocarpus*, etc.

ii) *Upper midlittoral zone :* This green belt is composed of algae like *Ulva beytensis, Ulva fasciata, Enteromorpha* sp., *Cladophora* sp. and *Struvea* sp.

iii) *Lower midlittoral zone :* This zone is characterised by the abundance of brown algae in this belt and includes algae like *Colpomenia sinuosa, Iyengaria stellata, Hydroclathrus clathratus,* *Boodlea sinensis*, *Sargassum* spp and *Cystoseira* sp. In the shallow water puddles algal population is represented by the species of *Caulerpa, Cladophoropsis, Laurencia, Gracilaria, Halimeda* and *Udotea*.

iv) *Infralittoral zone* : Species of *Champia Gracilaria, Padina, Gastroclonium* are the characteristic of this zone.

The shallow puddles in this zone show abundant and varied growth of *Halymenia porphyroides, Scinaia indica, Scinaia hatei, Grateloupia indica, Sebdenia polydactyla*.

In the rock pools of this belt, thick growth of coralline algal species like *Amphiroa, Jania, Cheilosporum* is observed. *Gracilaria* and *Laurencia* are found in association.

Seasonal variation has accounted for the algal population of each belt.

Approximately 120 marine algae belonging to chlorophyta, (18 gen. 33 sp), Phaeophyta (20 gen. 33 sp), Rhodophyta (43 gen. 54 sp.) have so far been reported from this island.

CONCLUSIONS

1. Flora of Beyt island shows predominance of marine algae. Species diversity and abundance of maire algal flora is supported by various environmental factors. In comparison with the land plants there is minimum environmental and biotic pressure on marine algae.
2. Terrestrial vegetation is adversely affected because of scanty rainfall and arid climate. Therefore, only xerophytic plants grow under these conditions because of their ability to withstand wide range of temperatures and edaphic conditions.
3. Due to the paucity of food, fodder and fuel there is over exploitation of land plants by the local people.
4. Although the muddy shore facing the mainland is suitable for mangrove growth, the fast water current and tidal bore of 6-7 m prevent their establishment and growth.

ACKNOWLEDGEMENTS : Authors wish to express their sincere thanks to the Director of National Institute of Oceanography for providing facilities. The second author gratefully acknowledges Indo-US project for the award of fellowship.

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Indian Journal of Marine Sciences
Vol. 18, September 1989, pp. 207-209

Marine algal flora of submerged Angria Bank (Arabian Sea)

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Received 22 August 1988; revised 21 June 1989

Submerged Angria Bank was surveyed for the deep water marine algal flora. About 57 species were reported from this bank for the first time. Rhodophyta dominated (30 species) followed by Chlorophyta (18 species) and Phaeophyta (9 species). A few species like *Valonia ventricosa, Halimeda discoidea, Galaxaura marginata, G. lapidescens, G. lenta, Hypnea pannosa, Botryocladia skottsbergii, Antithamnion* sp., *Acanthophora muscoides, Laurencia paniculata* and *Dictyurus purpurescens* were the first records from the west coast of India. Other genera like *Codium, Microdictyon, Dictyopteris, Dictyota, Sargassum, Galaxaura, Asparagopsis, Acanthophora* and *Laurencia* were predominant at the Angria Bank.

Most of the marine algal studies undertaken in India so far are from the intertidal region[1-3]. There are however, interesting reports on deep water marine algae from other regions. These data are quite important from distribution, physiology and reproduction points of view.

Angria Bank is located in the Arabian Sea approximately 135 km off Vijaydurg (16°27'N and 72°05'E) along the central west coast of India (Fig. 1). It has an area of 540 km^2. The average depth of water over the bank is about 25 m. Angria Bank has risen from the sea floor measuring 250 m depth. Nair *et al.*[4] have collected the environmental data from this bank. There is, however, no data available on the marine algal flora of any submerged bank along the Indian coast. This communication reports for the first time results of a systematic survey on marine algal distribution from Angria Bank.

Observations were made during three cruises of *R.V. Gaveshani* nos. 159 (December 1985), 169 (May, 1986) and 173 (October 1986). A bucket dredge (size 0.7 × 0.5 × 0.25 m) was used for collecting the samples at 13 stations (Fig. 1) along the preplanned transects so that maximum surface area is represented. Algal samples were cleaned and preserved as herbaria and also in 5% seawater formalin. All the specimens were deposited at NIO Reference Centre, Goa, India.

Although the surface hydrography was not directly relevant to the present investigations, the midwater environmental conditions are of great significance for the marine algal growth on the submerged bank. According to Nair *et al.*[4] the midwater temperature was found to be around 24.8° to 27.8°C, while salinity fluctuated between 35 and 36 × 10^{-3} and dissolved oxygen was 5.7 ml.l^{-1}. They have also reported significantly higher calcium concentration (1030 to 1915 ppm) from the shallow and submerged Angria Bank.

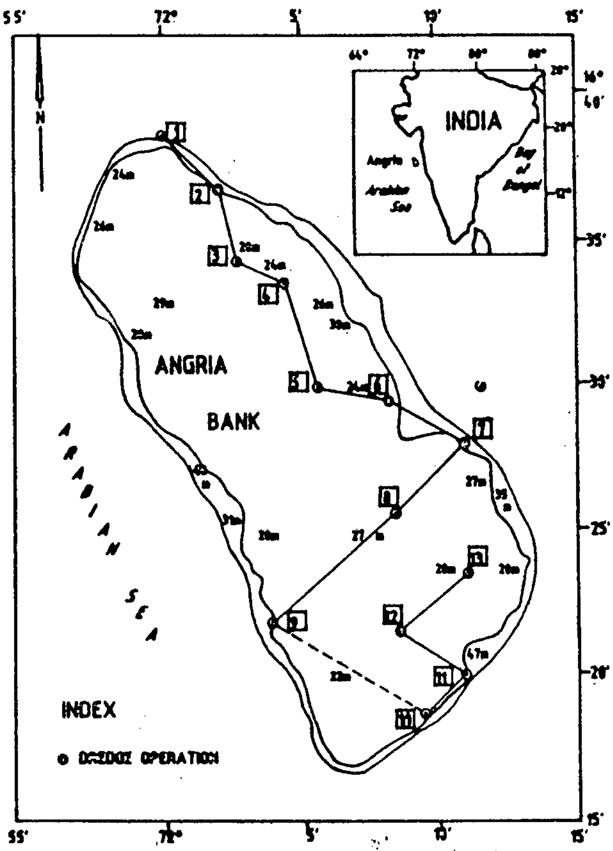

Fig. 1 – Map of Angria Bank showing locations of stations dredged

Table 1 – Marine algal flora of Angria Bank
[* = new records for the west coast of India]

CHLOROPHYTA

1. *Avrainvillea* sp.
2. *Boergesenia forbesii* (Harv.) Feldm.
3. *Caulerpa cupressoides* (Vahl) C. Ag.
4. *C. racemosa* (Forssk.) W.V. Bosse.
*5. *Chlorodesmis hildebrantii* A. Gepp et. E.S. Gepp
6. *Cladophora* sp.
7. *Codium elongatum* Boergs
8. *C. indicum* Dixit
*9. *Halimeda gracilis* Harv. ex. J. Ag.
10. *H. discoidea* Decaisne
*11. *H. tuna* f. *platydisca* (Decaisne) Barton.
12. *Microdictyon tenuis* (C. Ag.) Decaisne
13. *Neomeris annulata* Dickie
14. *Struvea anastomosans* (Harv.) Piccone
15. *Udotea indica* A. Gepp. *et.* E.S. Gepp.
16. *Valoniopsis pachynema* (Mertens) Boergs
17. *Valonia aegagrophila* C. Ag.
*18. *V. ventricosa* J. Ag.

PHAEOPHYTA

1. *Dictyopteris australis* Sonder.
2. *D. delicatula* Lamour.
3. *Dictyota dichotoma* (Huds) Lamour.
4. *D. maxima* Zanard.
5. *Lobophora variegata* (Lamour.) Wom.
6. *Padina pavonica* (L.) Thivy ex Taylor
7. *Ralfsia* sp.
8. *Sargassum* sp.
9. *S. tenerrimum* J. Ag.

RHODOPHYTA

*1. *Acanthophora muscoides* (L.) Boergs
2. *A. najadiformis* (Delile) Papenfuss.
3. *Acrochaetium* sp.
4. *Agalothamnion byssoides* (Arn. ex. Feldm.)
5. *Amphiroa fragilissima* (L.) Lamour.
*6. *Antithamnion* sp.
7. *Asparagopsis taxiformis* Delile
8. *Bostrychia tenella* (Vahl.) J. Ag.
*9. *Botryocladia skottsbergii* (Boerg.) Levr.
10. *Champia parvula* (C. Ag.) Harv.
11. *Ceramium rubrum* (Huds.) C. Ag.
12. *Ceratodictyon variabilis* (Gress.) R.E. Nomis.
13. *Cryptonemia undulata* Sond.
*14. *Dictyurus purpurescens* Bory.
15. *Fosliella farinosa* (Lamour.) Howe.
*16. *Galaxaura lapidescens* (Ellis *et* Sol.) Lamour.
*17. *G. lenta* Kjellman.
*18. *G. marginata* (Ellis *et* Sol.) Lamour.
19 *G. oblongata* (Ellis *et* Sol.) Lamour.
20. *Gracilaria* sp.
21. *Herposiphonia tenella* C. Ag.
*22. *Hypnea pannosa* J. Ag.
23. *Jania rubens* L. Lamour.
*24. *Laurencia paniculata* (C. Ag.) J. Ag.
25. *L. obtusa* (Huds) Lamour.
26. *Myriogramme bombayensis* Boerg.
27. *Nitophyllum punctatum* (Stackh.) Grev.
28. *Peyssonelia obscura* Web. V. Bosse.
29. *Polysiphonia* sp.
30. *Rhodymenia australis* Sond.

About 12 calcified marine algae have been reported in the present investigation. Among these forms *Halimeda* spp were found to be dominant. The phosphate values varied from 1.6 to 9.7 μg-at.l^{-1}.

The marine algal flora of the Angria Bank comprises 57 species representing 45 genera (Table 1). Most of these species are common for the main coastland or Lakshadweep atolls[2,3,5]. It appears that the flora of Angria Bank has greater affinity with the flora of Gulf of Kuchchh and Maharashtra than with the flora of Lakshadweep[5]. The species of *Codium, Microdictyon, Dictyopteris, Dictyota, Sargassum, Galaxaura, Asparagopsis, Acanthophora* and *Laurencia* were abundant during the investigation. It was also observed that most of the seaweeds grew luxuriantly on the ridge (Fig. 2) towards mainland as compared to the other side. The central part of the bank, however, supported growth of live coral species of *Turbinaria*, which perhaps prevents the growth of any vegetation. Of the species reported a few species like *Halimeda gracilis, H. discoidea, Valonia ventricosa, Acanthophora muscoides, Antithamnion* sp., *Botryocladia skotsbergii, Dictyurus perpurescens* and 3 species of *Galaxaura* are new re-

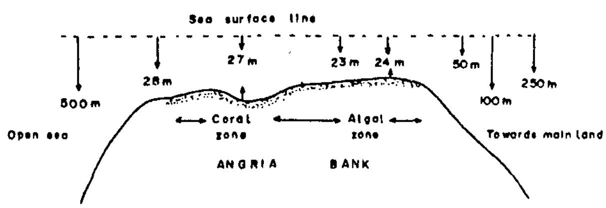

Fig. 2 – General profile of the Angria Bank showing coral and algal zone

ports for the west coast but already listed from the east coast[6].

Authors are thankful to Director, NIO, for facilities. C.R.K. Reddy and V.D. Ambiye gratefully acknowledge the financial help received from Department of Ocean Development and Indo-US PL 480 project Bioactive compounds from the marine organisms, respectively.

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