

Letter Section

Seasonal variation in an annually-banded coral *Porites*:
A scanning electron microscopy investigation

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Abstract

Seasonal bands of the hard coral *Porites* sp. collected from three different islands of Lakshadweep (Northwest Indian Ocean) are examined under a scanning electron microscope (SEM). SEM photographs reveal the presence of detrital inclusions in high density bands and their absence in low density bands. It is proposed that during the monsoon season, run-off from the island may bring detrital material that subsequently gets incorporated in coral skeleton. By contrast, calm and dry conditions prevailing during the non-monsoon period preclude such incorporation due to non-availability of detrital material in the water column. In addition to the inclusions of detrital material, the presence of low-Mg calcite and carbonate cementation in seasonal bands are also observed.

1. Introduction

Scanning electron microscopy (SEM) has long been used to investigate small-scale features such as microarchitecture and microstructure of scleractinian corals (Barnes, 1970; Wise, 1970; Jell, 1974; Oekentorp, 1974; Isa, 1987). Gladfelter (1983) illustrated the temporal sequence of events in the development of the skeleton of *Acropora cervicornis*. Patzold (1984) reported that individual dissepiments within the structure of the coral skeleton are about 140 μm wide in the low density areas and 210 μm wide in the high density zones.

SEM studies have also revealed the presence of calcite in the coral skeleton (Houck et al., 1975; Schneider and Smith, 1982); and the presence of calcite is found to be an indicator of post-

depositional changes in Sr and Mg concentration (Schneider and Smith, 1982; Yoshioka et al., 1985). This technique further helps in detecting the aragonite cement in the coral (Patzold, 1988), which has a Sr content distinctly different from the other parts of the coral itself (Patzold, 1988). Hidaka (1988) utilized SEM to study the crystal shapes of aragonite and the effect of light intensity during the growth of these crystals.

The Lakshadweep group of islands are located in the Northwest Indian Ocean (Fig. 1) in a region that comes under the influence of the monsoons. This introduces marked seasonality in the environmental conditions under which the corals grow. However, no attempt has been made so far to use the SEM technique to investigate small scale features in the seasonal bands of corals from this region. Results of the first ever investigation on a

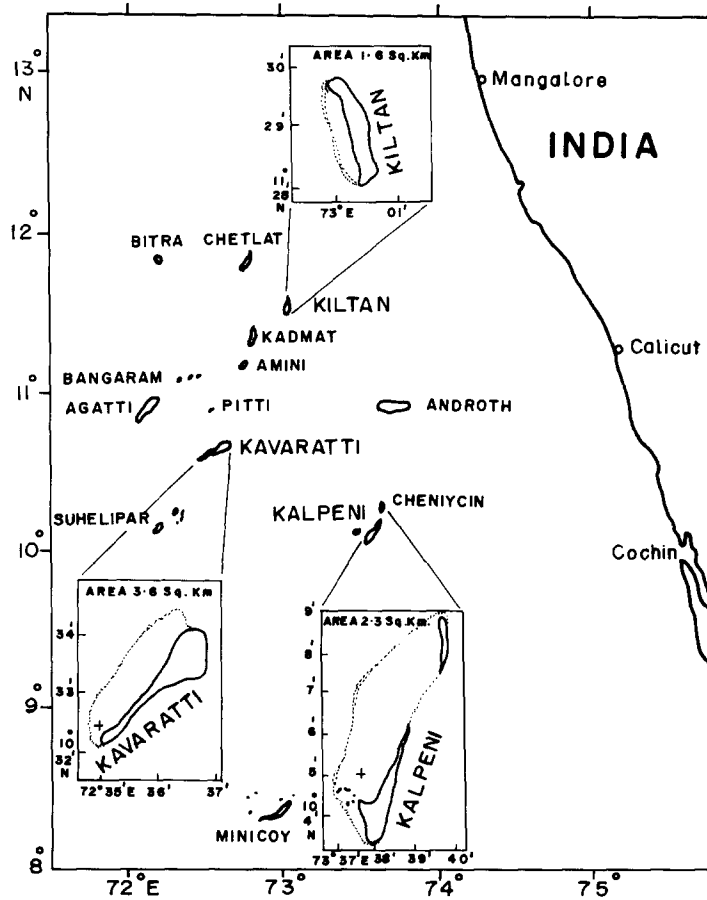


Fig. 1. The Lakshadweep islands. Insets show sampling sites marked by (+) within the lagoons of the three atolls Kiltan, Kavaratti and Kalpeni.

reef-building coral *Porites* sp. from this area are reported in this paper.

2. Material and methods

Porites samples were collected from the lagoons of the atolls Kiltan (11°29'N, 73°E), Kavaratti (10°33'N, 72°38'E) and Kalpeni (10°05'N, 73°39'E) in the Lakshadweep (Table 1; Fig. 1). Each specimen was sectioned by a water lubricated diamond cutter. Utmost care was taken to obtain a parallel sided slab of 5 to 8 mm thickness containing the axis of maximum growth of the coral. Subsequently, each slab of the sample was X-rayed for 3 minutes on Agfa Gevaert industrial X-ray film from a distance of 1 m, 50 kV, 2.7 mA in a

closed chamber. Since the corals were collected alive, the dating of density band of the samples were assigned on the basis of the date of collection as a time base line (Weber and White, 1974; Isdale, 1977; Wellington and Glynn, 1983; Brown et al., 1986; Naqvi, 1991).

Subsequently, small pieces of *Porites* comprising two to three seasonal bands, were taken from the slabs of the Kiltan, Kavaratti and Kalpeni samples, sputter coated with gold and were scanned on JEOL JSM-840 scanning electron microscope.

3. Results

The X-radiographs (Fig. 2) revealed that the corals have alternating low and high density bands

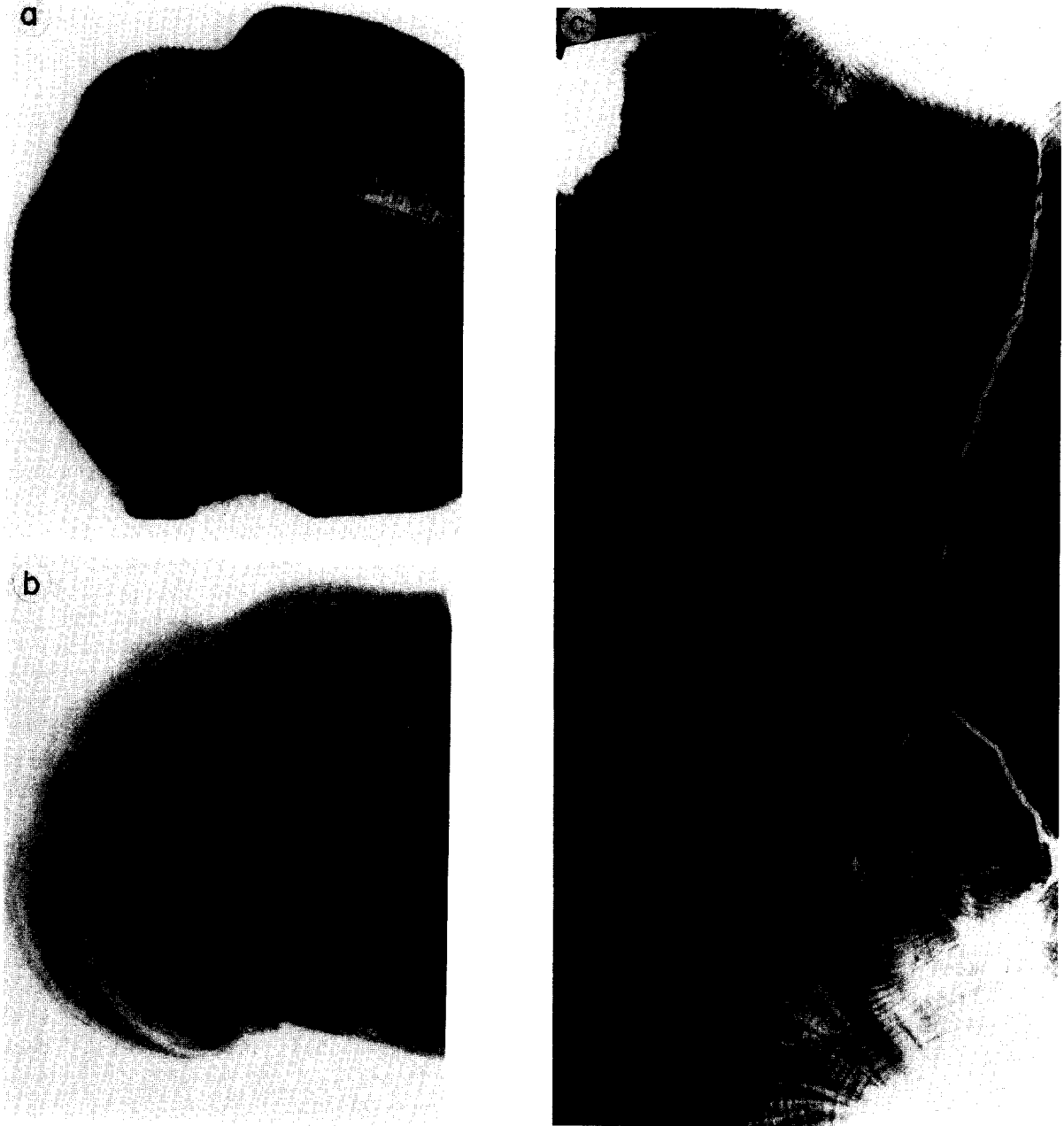


Fig. 2. X-radiographs of a recent colony of *Porites* illustrating alternate bands of high and low skeletal density collected from (a) Kiltan, (b) Kavaratti and (c) Kalpeni atolls.

and are concordant with the growth of the colony (Naqvi, 1990, 1991).

The electron micrographs of the Kiltan sample are presented in Fig. 3. The low density band of the year 1988 (Fig. 3a) shows endolithic algae. In

the high density band of 1987, the SEM photograph reveals the presence of few low-Mg calcite crystals (Fig. 3b). Shell fragments (Fig. 3c) and other entrapped detrital material (Fig. 3d) are also observed in the same band, whereas the low

Table 1
Details of sample collection is presented with the characteristic features

Site	Location	Water depth	Species	Seasonal band	Year	Inclusions	Remark
Kiltan atoll	11°29'N 73°E	1.5	<i>Porites</i>	Low density	1988	Absent	Endolithic infestation Low Mg-calcite
				High density	1987	Present	
				Low density	1987	Absent	
Kavaratti atoll	10°33'N 72°38'E	2.0	<i>Porites</i>	Low density	1988	Absent	Carbonate cementation
				High density	1987	Present	
				Low density	1987	Absent	
Kalpeni atoll	10°05'N 72°38'E	1.5	<i>Porites</i>	High density	1977	Present	
				Low density	1977	Absent	

density band of 1987 shows empty cavities (Fig. 3e).

Similarly, the sample from Kavaratti lagoon shows the absence of any detrital inclusion in the low density band of 1988 and 1987 (Fig. 4a and e). The high density band of 1987 does not reveal anything at lower magnification (Fig. 4b), whereas at higher magnification detrital inclusions are clearly seen (Fig. 4d). However, even at the lower magnification the occurrence of carbonate cementation is observed in the low density band of 1987 (Fig. 4c).

SEM examination was also carried out on the low and high density bands of 1977 of the Kalpeni sample. It is noticed that they have a minor difference in their characteristic features (Fig. 5a and b, respectively).

4. Discussion

Results obtained from SEM studies of the coral samples reveal significantly different environmental conditions prevailing at their time of formation. Some infestation of the coral by endolithic algae can be seen in the low density band of 1988 (Fig. 3a). Similar infestation has been reported previously by Patzold (1988), Macintyre and Smith (1974) and Buddemeier et al. (1974). The high density band of 1987 reveals well developed crystals (Fig. 3b) of low-Mg calcite. This has also been confirmed from X-ray diffraction analysis (Naqvi, 1991). Similar crystals were also reported by Houck et al. (1975), Schneider and Smith

(1982), Gladfelter (1983) and Johnson et al. (1984) in *Porites* and some other species of corals. The crystals are clean, blocky and rather angular possessing no internal structure (Fig. 3b). They occur internally within the skeletal structures and show no evidence of occupying pre-existing skeletal cavities. This indicates that the skeletal calcite might have been formed by the coral itself (biogenic origin), as an alternate form of calcification. A similar process has been suggested by Houck et al. (1975) for the occurrence of skeletal calcite in *Porites lobata* of Oahu, Hawaii. Barnes (1970) suggested that calcite could be the initial mineral deposited in all larval scleractinian skeletons. However, Macintyre and Towe (1975) pointed out that calcite can also be deposited by boring organisms.

Shell fragments (Fig. 3c) and entrapped particles (Figs. 3d and 4d) in the high density band of *Porites* strongly suggest detrital input to the sites of coral growth by the run-off of rain water (Livingston and Thompson, 1971; Barnard et al., 1974; Naqvi, 1994). The low density bands (Figs. 3e and 4a,e), on the other hand, clearly indicate the absence of detrital material. But the absence of detrital material is not that much clear in the non-monsoon band (1988) of the Kiltan sample due to the endolithic infestation (Fig. 3a).

Even at a lower magnification the Kavaratti coral (*Porites*) sample (Fig. 4c) clearly shows the presence of carbonate cementation in the non-monsoon band of the coral. Patzold (1988) found aragonite cements, even a few years after skeletal

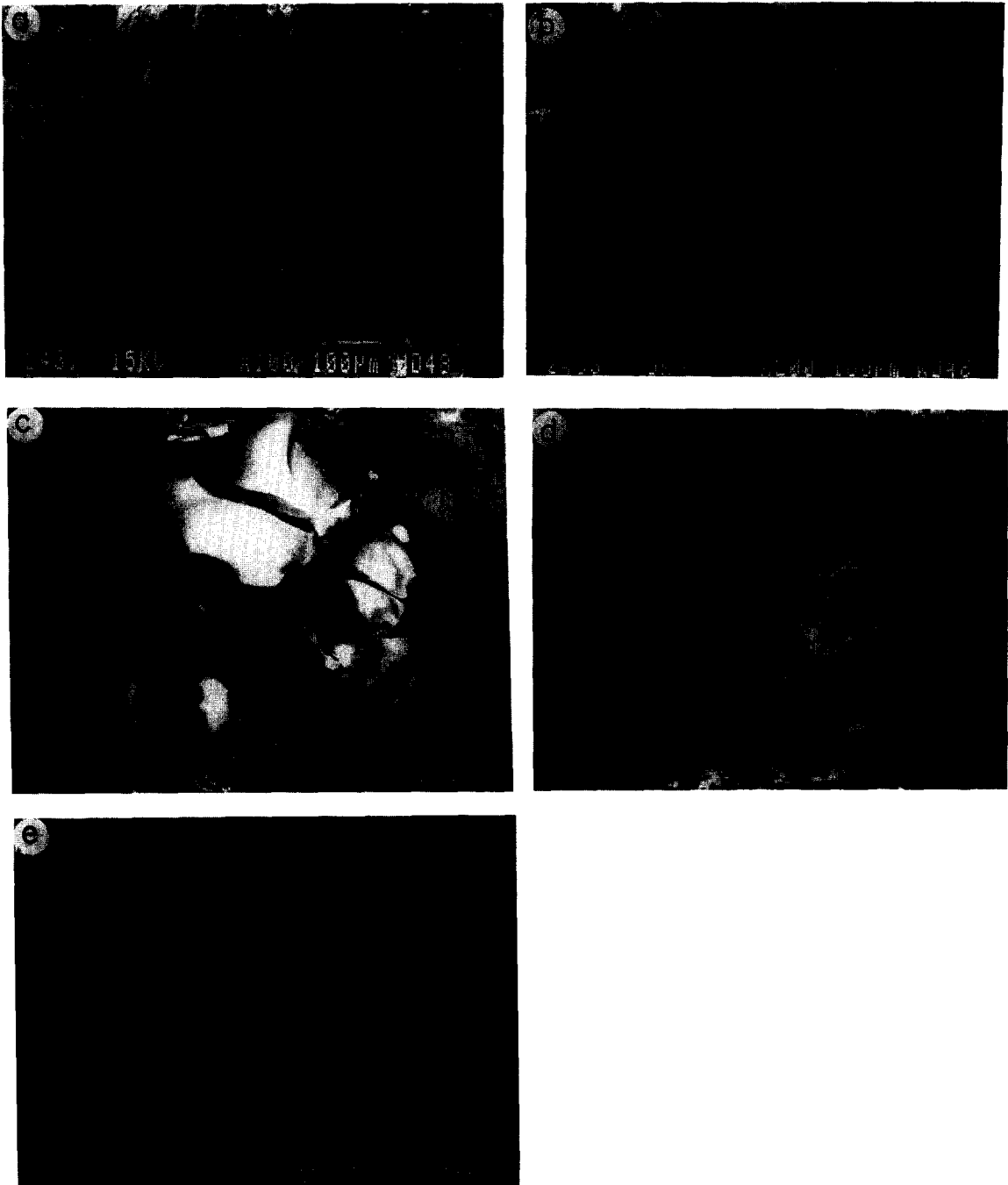


Fig. 3. Scanning electron microscopy of low and high density bands of the Kiltan sample. (a) Low density band representing the year 1988 shows infestation of endolithic particles. (b) Arrows show location of low Mg-calcite in the high density band of 1987. (c) Presence of shell fragment in the same seasonal band. (d) Similar band also reveals incorporation of detrital particles. (e) Empty spaces can be noticed in the low density band of 1987.

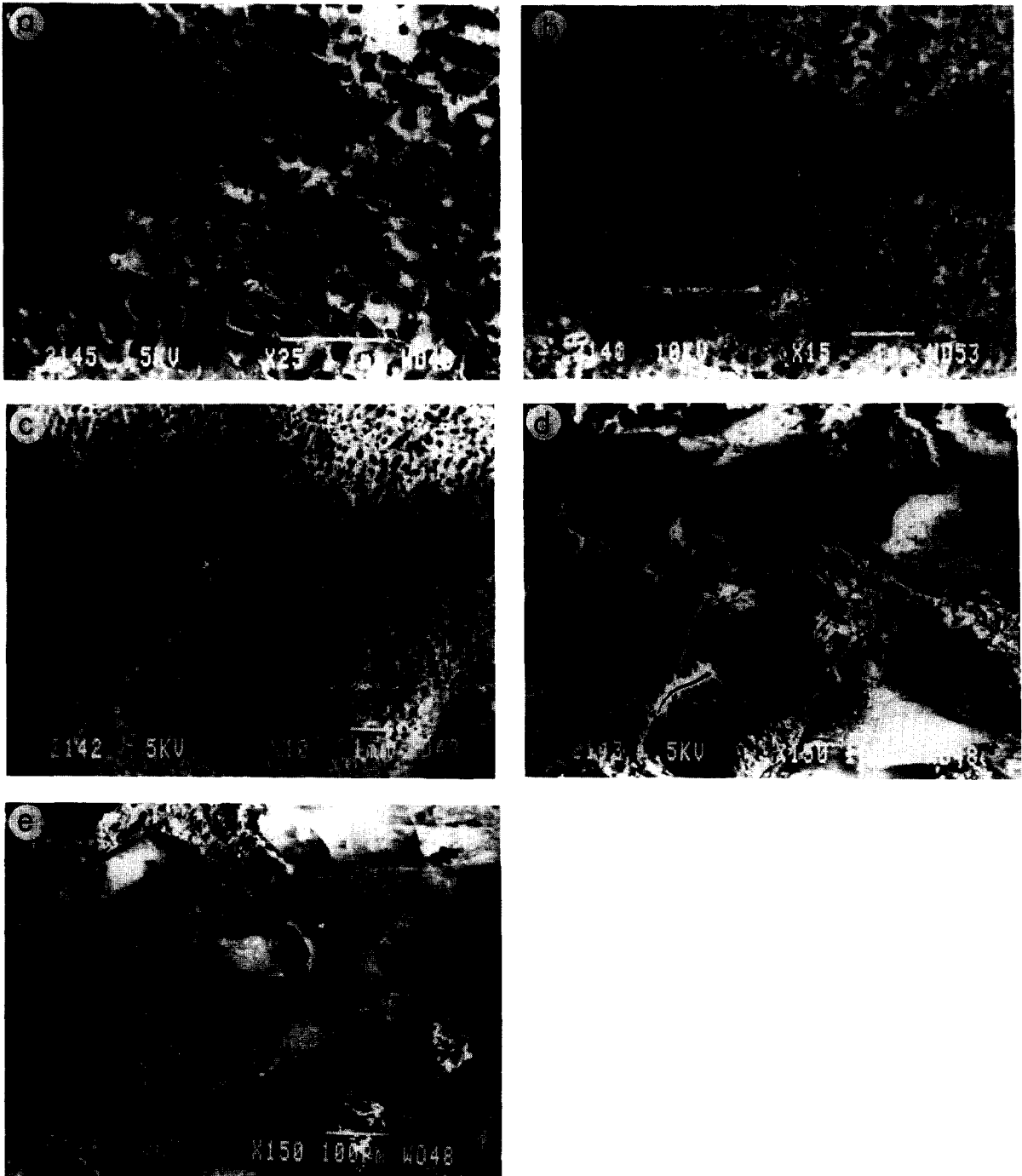


Fig. 4. SEM images of different seasonal band samples of Kavaratti atoll. (a) Empty spaces in the low density band of 1988. (b) High density band of 1987 at lower magnification. (c) Low density band of the same year reveals the presence of carbonate cementation even at lower magnification. (d) Higher magnification of the high density band (1987) reveals the presence of entrapped particles. (e) Similar year (1987) low density band reveals the absence of foreign bodies on higher magnification.

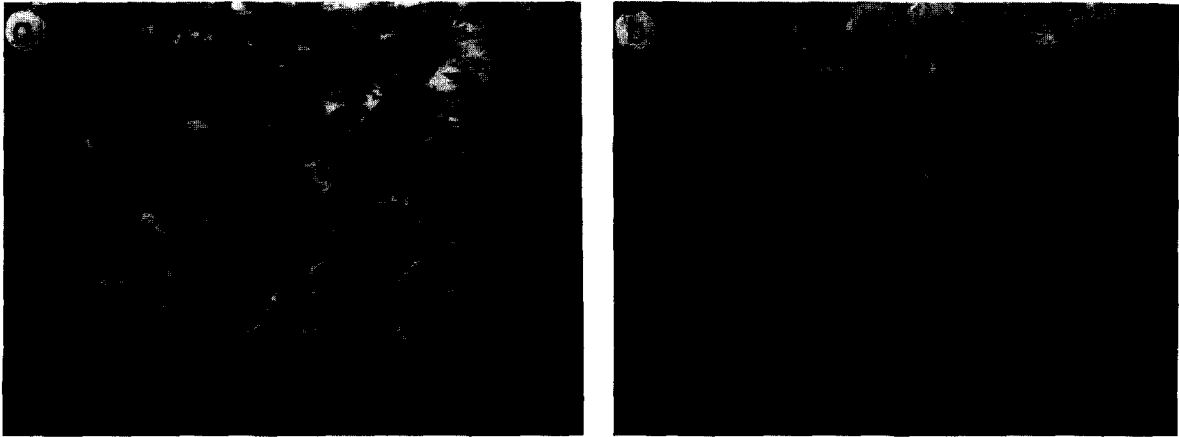


Fig. 5. Scanning electron micrographs of: (a) low density band and (b) high density band of the year 1977 collected from Kalpeni atoll sample.

deposition in *Porites lobata* from Cebu, Philippines. Johnson et al. (1984) also recorded intracorallite aragonite cement. SEM photographs of low density (Fig. 5a) and high density bands (Fig. 5b) do not show prominent differences. On close observation the high density bands (Fig. 5b) reveals more infillings and a lesser number of empty polyps compared to the low density band (Fig. 5a) indicating the effect of rainfall. This is further supported by the rainfall data for Minicoy island (Naqvi, 1991). Which shows that rainfall was quite less in Minicoy island during the monsoon season in 1977 as compared to other monsoon seasons.

From these studies it appears that during the monsoon, greater run-off and detrital input are supplied to the corals which appear as infillings of polyps. The type of material occurring as inclusions can be ascertained by further studying these inclusions chemically by EDAX, which will also help to determine the provenance.

5. Conclusions

SEM photographs of the annually banded coral *Porites* sp. appear to show significant differences in the environmental conditions under which calcification occurred during various seasons. The low density bands, which are formed during the non-monsoon period, generally do not contain detrital

particles. The monsoonal bands in contrast, frequently entrain foreign bodies in their cavities reflecting higher suspended detrital concentrations. Present work confirms the occurrence of calcite crystals and carbonate cementation in the coral skeleton. It has been reported (Schneider and Smith, 1982; Patzold, 1988) that the occurrence of calcite indicates lower Sr and Mg concentrations and that carbonate cementation affects the Sr concentration as well as oxygen and carbon isotopic composition. Therefore, the reconstruction of the paleoenvironment based on geochemical and isotopic analyses may suffer from the occurrence of detrital inclusions, calcite and carbonate cementation and care must be taken to avoid these features.

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