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Paleothermometric fluctuations and ornamentation pattern of Ostracoda species from a short core, off Ongole, Bay of Bengal, South-east Indian coast

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An investigation on the elemental chemistry and its fluctuation in Ostracoda carapace to render the environmental traits from off Ongole, Andhra Pradesh is outlined in the paper. Paleothermometric elucidation of the environment using elements Ca, Mg, As, Nb, Sb, Al, Si, Cl, K and Na and the ornamentation pattern exhibited by Ostracoda are identified and ventilated. A short core of length 20 cm was collected from the study area using a multicorer during the ORV Sagar Kanya cruise (SK-308 Leg 1) fieldwork, at a water depth of 47 m. Ostracoda separated from the sediment matrix were subjected to standard micro-paleontological procedures. The elemental weight percentages reveal that the distribution of the elements in the carapace for different species is not the same and fluctuates along the downcore. The occurrence of Niobium in the offshore sediments is observed to be of terrestrial influence, which is derived from granitic and pegmatite rocks of the adjoining coastal terrain. A traceable quantity of Antimony and Arsenic is identified in the carapace of the certain Ostracoda. Mg/Ca ratio in carapace indicates that an endurance of mild temperature fluctuation to the downcore. Smooth, spinose, pitted, punctate and reticulate ornamentation are found occurring in Ostracoda carapace which reflects on the depositional environment and granulometry.

[**Keywords**: Bay of Bengal, Element partitioning, Ornamentation, Ostracods, Shell microchemistry]

Introduction

Ostracods are bivalved micro arthropods with distinguished limbs and a furca all of which lacks growth lines in their carapace[1]. They are sensitive to the minute environmental changes. Their presence in all aquatic environments, make them a successful proxy in inspecting environmental health as well as ecological characteristics of an area. Normally they grow in a size range from 0.5 to 1 mm and need a careful study under microscope to determine the carapace characteristics. The microcrustaceans in their life shed their exoskeleton 8 times, during their growth stages until they become adults. This process of removal of their exoskeleton is known as moulting or ecdysis. Ostracod moulting results in shedding of the complete exoskeleton of carapace and appendages[2]. Ostracods are likely monophyletic and of Cambrian origin[3]. The earliest fossil record of Ostracoda was reported from Ordovician marine rocks[4]. Diverse sedimentological facies support distinct Ostracoda assemblages[5]. Ostracoda distribution is controlled by grain size, sorting coefficient and presence or absence of bottom vegetation[6]. They are specifically used to reconstruct paleoecology on the distribution and diversity, especially with respect to the salinity, temperature, substrate and depth[7]. The microfauna can be used as a tool to decipher past and current ecological conditions of aquatic habitats[8,9]. The weight percentage of Cobalt (Co), Nickel (Ni), Copper (Cu), Zinc (Zn), Cadmium (Cd), Lead (Pb), and Rare Earth Elements (REE) in Ostracoda shells indicates the levels of urban and industrial pollution[10]. Arsenic (As) sources in ocean surface are attributed to upwelling of deep ocean water as well as riverine inputs[11,12]. Anthropogenic activities donate little arsenic to the open ocean[13]. The Mg/Ca ratio of the Ostracods can be used to determine the temperature variations in an area[14]. A strong correlation has been noted between Total Dissolved Solids (TDS) and Mg/Ca ratios. The studies on Mg/Ca are useful in determining salinity[15]. Mg/Ca in Ostracoda valves strongly correlates with the respective Mg/Ca in water[16].

Materials and Methods

Field work

In order to have a clear picture of the most recent Ostracoda from the area, a short core was collected from off the coast of Ongole, Bay of Bengal (Fig. 1). The Bay of Bengal is located on the north-eastern part of the Indian Ocean. The short core retrieved was having a length 20 cm, collected using a multicorer during the Sagar Kanya ORV cruise SK 308 leg 1, at a depth of 47 meters. The geographical coordinates of the sampling station are 15°29’08” N (Latitude) and 80°29’08” E (Longitude), respectively.

Sample treatment

Twenty sub-samples were obtained by further sampling the sediment core at an interval of 1 cm and are subjected to standard micropaleontological and shell geochemistry analyses. For Electron Dispersive X-ray Spectroscopy (EDS), 7 subsamples were made from the core at an interval of 3 cm. From the sediments, the Ostracod carapaces were handpicked and transferred to micropaleontological slides and mounted over a thin layer of tragacanth gum. The different genera and species were identified; type specimens of each species were selected and transferred to taped copper stubs in which the microfossils are mounted for Scanning Electron Microscopy (SEM) and EDS.

SEM and EDS

Scanning electron microscope imagery and EDS are the proxies used in the present study. Scanning electron microscope imagery is used for morphological studies and illustration of microfossils. A focused beam of electrons is arranged and it gets bombarded with sputtering gold plated microfossils. The electron gets interacted with atoms in the microfossils and SEM photographs can be plotted.

Energy dispersive X- ray Spectroscopy is used as an elemental analysis for determining the chemical composition of the samples. The electron beam on the sample produces X-rays that are characteristic of the

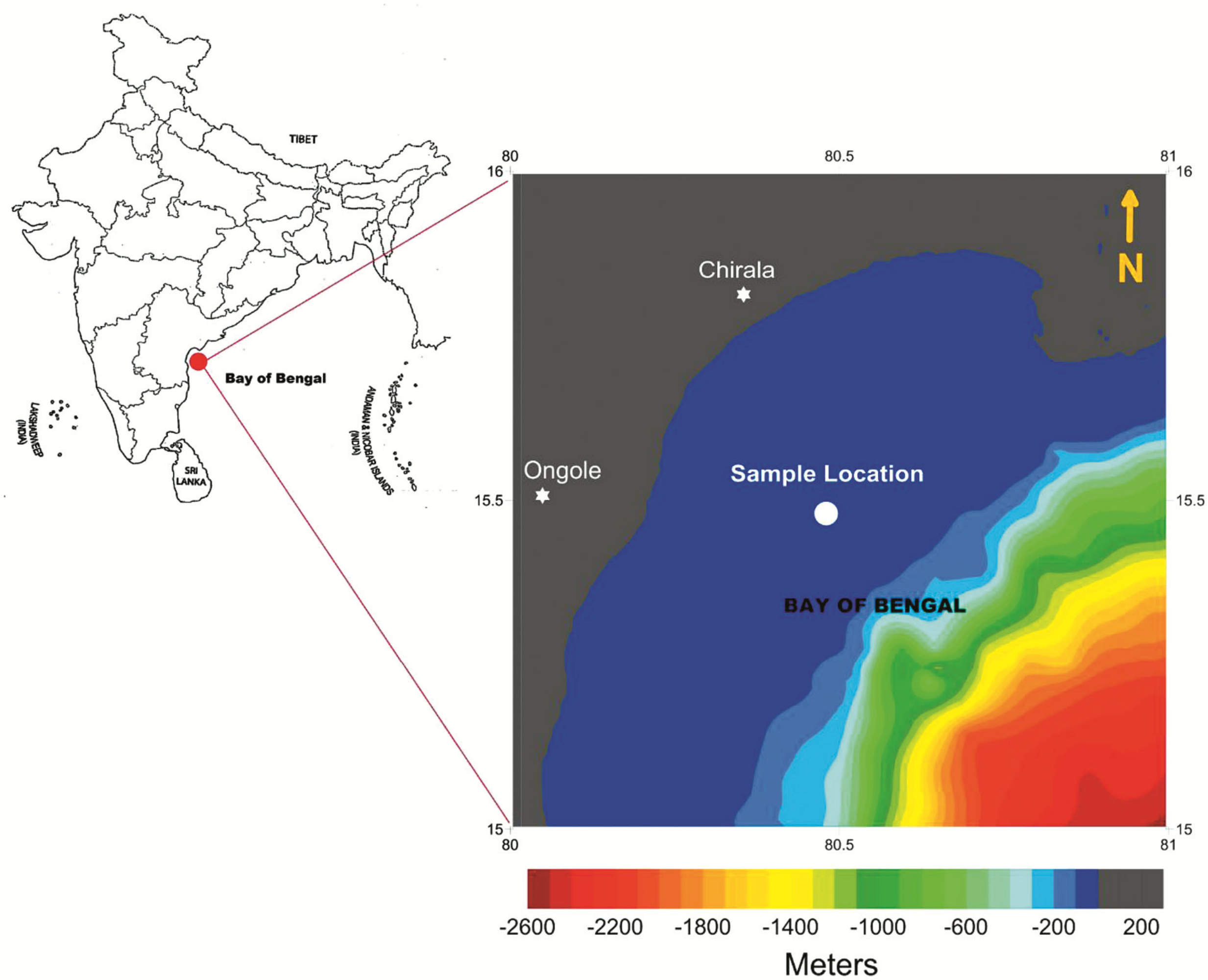

Fig. 1 — Bathymetry map of study area and sampling location

element present on the sample. These X-ray pattern traces the elemental composition. EDS is also a prominent tool in deciphering the clay mineral composition. Also, EDS is used in understanding the environmental pollution and helps in reviewing tissues of organisms[17].

Results and Discussions

Distribution of Ostracoda

To be specific 41 Ostracod taxa belonging to 33 genera of the order Podocopida have been identified from the location[18]. Two species belongs to suborder Platycopa and 39 species are categorized under suborder Podocopa. Ostracoda species identified are shallow, inner shelf, tropical in nature and are of Indo-Pacific origin. Fine grained silt and clay which reflects on the low energy condition of sediment deposition in the area contribute to the occurrence of well ornamented and large sized Ostracoda. In top core highly ornamented forms are dominant and to the downcore smooth forms are abundant (Fig. 2). *Bradleya andamanae*, *Actinocythereis scutigera*, *Pistocythereis bradyi* and *Bairdoppilata alcyonicola* are the dominant Ostracoda forms retrieved from the short core.

Shell microchemistry

The elemental weight percentage of Carbon (C), Oxygen (O), Sodium (Na), Magnesium (Mg), Potassium (K), Aluminium (Al), Silica (Si), Chlorine (Cl), Calcium (Ca), Arsenic (As), Niobium (Nb) and Antimony (Sb) have been estimated (Table 1) from the carapace of dominant Ostracoda taxa.

A recognizable amount of Niobium (Nb) was detected in the EDS analysis in every carapace through downcore. The source of the Niobium is natural in origin and the supply of the same is from the existing base granitic rocks and pegmatites. The presence of As and Sb in the Ostracod shell indicates pollution in the area. Carbon percentage in the

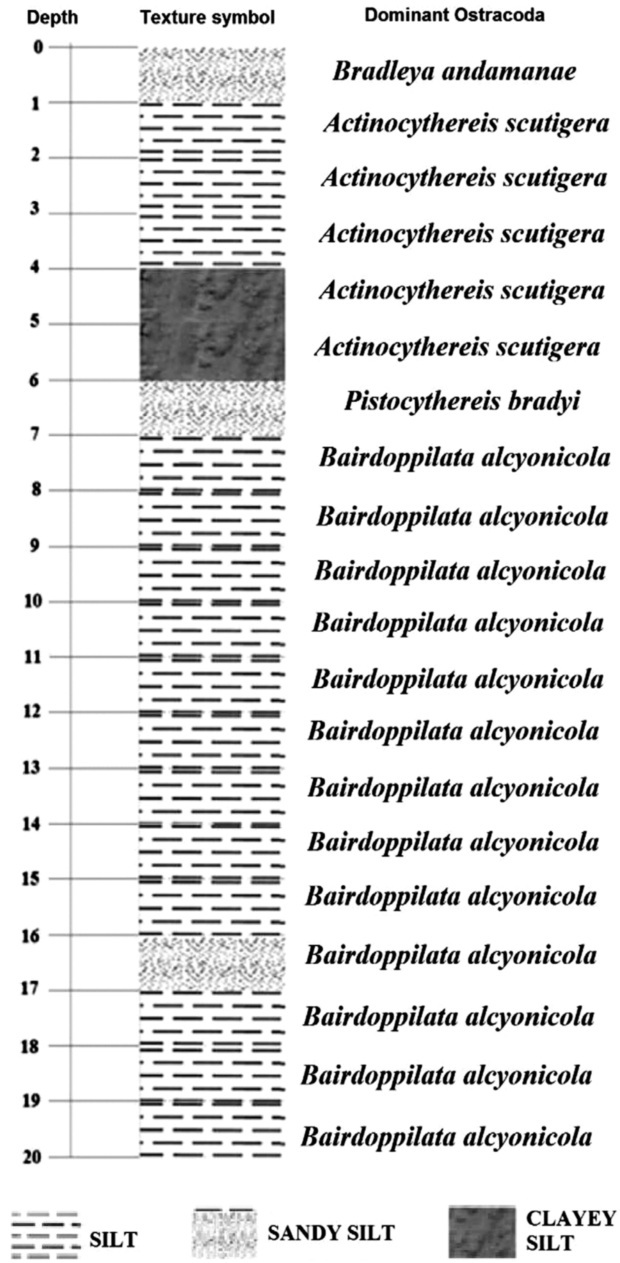

Fig. 2 — Distribution of dominant Ostracoda species to downcore

Table 1 — Shell microchemistry in Ostracoda carapace

Sample number	Elemental weight percentage in Ostracoda carapace (%)											
	C	O	Na	Mg	Al	Si	K	Ca	As	Sb	Cl	Nb
1	0	66.66	2.94	2.15	0.14	0.41	0.85	25.10	0.58	0	0	1.18
2	14.05	57.89	0.96	1.24	1.76	2.72	0.81	19.26	0.43	0	0	0.88
3	12.21	61.16	0.87	1.12	0.58	1.11	0.32	21.23	0	0	0	1.40
4	8.74	61.58	1.31	0.83	0.40	0.78	0.52	24.93	0	0	0	0,90
5	0	66.60	2.37	2.07	1.73	3.56	1.23	19.49	0	0	1.74	1.21
6	1.64	64.95	2.11	1.04	0.44	1.12	0.64	24.24	0	0	2.40	1.41
7	0	66.74	1.98	1.85	0.52	1.13	0.37	22.57	0	2.55	1.20	1.09

Ostracod shell varies from 1.64 to 14.05 %. Oxygen (O) value ranged from 57.89 to 66.74 %. Sodium (Na) varied from 0.96 to 2.94 %. Magnesium (Mg) having its lowest value of 0.83 and ranges to 2.15 %. Aluminium (Al), Silica (Si) and Potassium (K) ranged between 0.14 to 1.76 %, 0.41 to 3.56 % and 0.32 to 1.23 %, respectively. Calcium percentage varied between 19.26 to 25.10 %. The Niobium weight percentage (Nb) falls between 0.88 to 1.41 %. Arsenic and Antimony was detected only in a few fossil carapace. The Arsenic value ranges from 0.43 to 0.58 % and Antimony found present in *Keijella karwarensis*, with a percentage of 2.55 %. Importantly the presence of Arsenic is found only in the most recent species, *Bairdoppilata* (*Bairdoppilata*) *alcyonicola* and *Loxoconcha* sp. 1. The analysis of the result gives an idea that oxygen is having maximum weight percentage in the carapace all through downcore. The species with fewer body ornamentations are having less weight percentage of Carbon. In some forms the Carbon weight percentage is negligible.

Evident from the EDS data that the area is having a good oxygen supply, that is essential for the growth of the organisms. Consistent and a little concentration of Niobium found present throughout and the origin of which is from the terrestrial sediments. To be specific the occurrence of Niobium is from Titanium Niobium rich astrophyllite in Podili alkali granite which occurs near to the region[19].

Paleothermometric measurements

The determination of elemental chemistry of carbonate from organisms is important proxy in understanding past environments[20]. Ostracod shell chemistry from vivid environments is concerned mainly on the elements Mg and Sr to relate the water chemistry and temperature[21]. Mg/Ca values and the corresponding elemental weight percentage of the carapace have been plotted in Figure 3. The EDS identifies the presence of oxygen dominant bottom water environment and the Mg/Ca ratio studies elucidate existance of a slight temperature fluctuation through downcore. Ostracod population is influenced by the relative increase in temperature, salinity and the dissolved oxygen content of the bottom waters[22]. Variations in the structure of secondary pore patterns have been observed from the carapaces.

Mg/Ca ratio in Ostracoda carapace increases with an increase in temperature[23]. Multi-proxy studies near accurately measures the paleo-temperature; however, it is not possible to mention the approximate paleo-temperature fluctuations with Mg/Ca studies in Ostracod shell alone. Mg/Ca ratios of Ostracod carapace in the present study area is ranging from 0.64 to 0.11 %. A fluctuation in Mg/Ca reveals an existence of variation in temperature to the downcore.

Ornamentation patterns

Ostracoda specimens from the inner shelf, off Ongole, are well-developed and preserved adults and with different ornamentation patterns. The forms with punctate and reticulate ornamentations are dominant in top sediments but to the downcore smooth forms dominate. The smooth and finely pitted Ostracods forms prefer finer substrate, but the highly calcified and ornamented Ostracoda prefer coarse-grained sediments[24]. The specimens retrieved are having smooth, spinose, pitted, punctate and reticulate ornamentation.

The pore canal system in Ostracoda enables the animal to interact with the outer environment, even if the shell valves are closed[25]. Ostracoda taxa *Bairdoppilata* (*Bairdoppilata*) *alcyonicola* is having smooth external ornamentation with very minute pores. The reticulate Ostracoda *Bradleya andamanae*

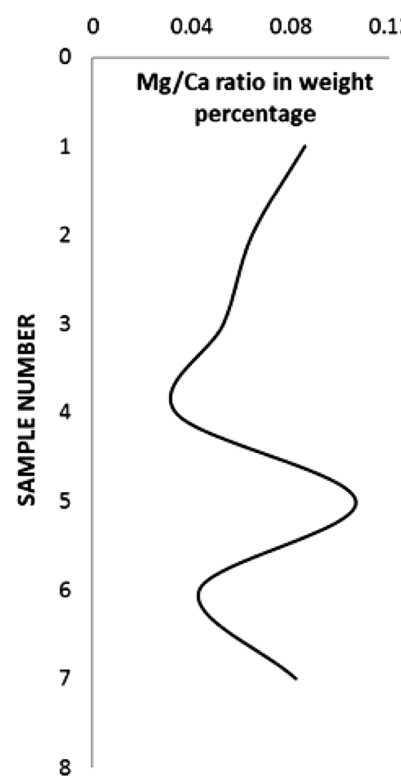

Fig. 3 — Mg/Ca ratio in Ostracoda carapace

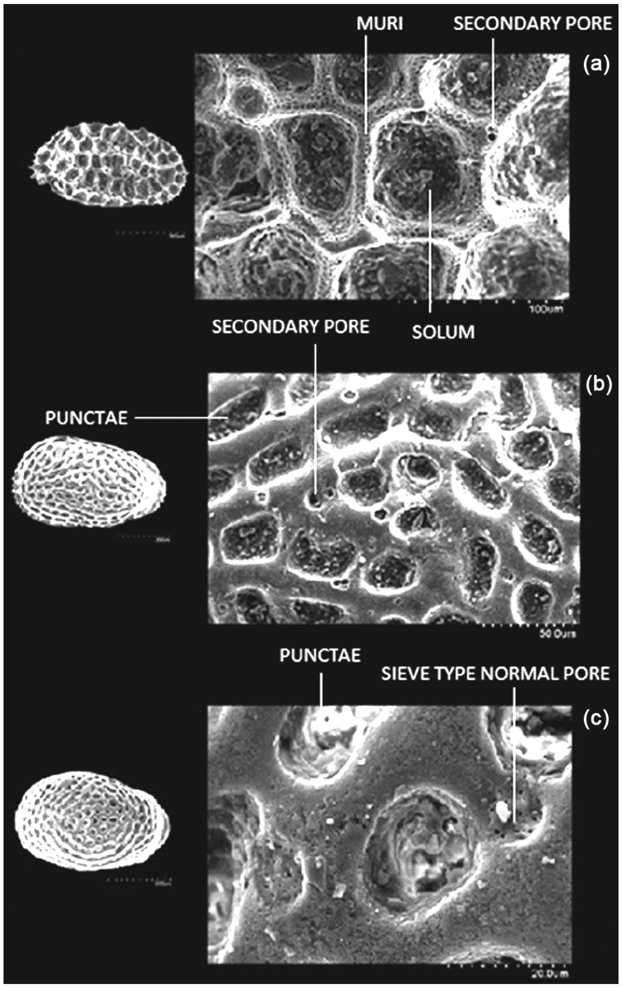

Fig. 4 — Ornamentation in Ostracoda: a) *Bradleya andamanae* Benson, 1972, b) *Keijella reticulata* Whatley & Zhao, 1988, and c) *Loxoconcha* sp. 1

have a distinguishable muri and solum (Fig. 4). The size, shape and pattern of the secondary pores in the ostracod exoskeleton varies through different genera. *Actinocythereis scutigera* is the important spinose form in the region. *A. scutigera* have thick shells with prominent tubercles and tubercular spines[26].

Even though different Ostracod ornamentation patterns are present in the area of study, majority of the species are having punctate (Fig. 4) and reticulate ornamentation. The ornamentation pattern do have a relation with the grain size. Sieve type normal pores has been observed in *Loxoconcha* sp. 1 (Fig. 4). Species like *Actinocythereis scutigera* thrive normally on sandy silt or silty sand.

Conclusion

Shell geochemistry indicates the existence of impact of anthropogenic activities in the region. Evident from the studies, Niobium sequestration varies for different Ostracod species, and its origin is believed to be of terrestrial. A traceable quantity of Antimony is noted downcore. Arsenic contamination is identified in the top core due to the offshore crude oil waste discharge. Mg/Ca studies describe that the region is having fluctuating paleothermometry. Ostracoda have an element imbibition capacity, in which a representative quantity of elements from the surrounding environment was added to their shell during the growth stages.

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Conflict of Interest

The authors have no competing or conflicts of interest to declare. All co-authors have seen and agreed with the contents of the manuscript. We certify that the submission is an original work and is not under review at any other publication.

Author Contributions

Manuscript Drafting: MNN; paper correction, modification and identification of Ostracoda: SMH; picking of Ostracoda: KVM; sampling and Fieldwork: NMN; and maps and plots: SD.

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