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Paleothermometric Inferences Using Elemental Mapping: An Appraisal of Ostracoda Species from Shallow Core Sediment of Bay of Bengal, India

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Abstract

Elemental mapping of Ostracoda valves to infer the paleothermometric fluctuations from off-Visakhapatnam, Bay of Bengal is the focus of the present paper. Two Ostracoda species such as *Bairdoppilata (Bairdoppilata) alcyonicola* and *Actinocythereis scutigera* were dominant throughout the core. The weight percentages of Mg, Sr, Ba, Fe and Mn in ostracod carapaces were estimated and the ratio with respect to Ca was analyzed to decipher the paleoclimate and oxy-redox conditions. It is observed that trace element accumulation varies with respect to different ostracod species and shell position. Thus, the elemental mapping of the ostracod carapaces by the EDS techniques proved as a primary proxy to decipher the paleotemperature fluctuations in the study area.

Keywords: Paleothermometry, Elemental Mapping, Ostracoda, Visakhapatnam, Bay of Bengal

Introduction

A comprehensive review of the Holocene environmental fluctuations is essential to understand the future environmental alterations. The changes in the past 11700 years in earth history drastically influence the human race as well. The microfossil group Ostracoda is widely used to demarcate the fluctuations in the past environments, rate of sedimentation, changes in temperature, variation in sea level changes, global cooling and warming events. The change in microenvironment of the ecosystem reflects on the micro-morphology of Ostracoda, which are used as a proxy in determining the paleotemperature, paleo-salinity and paleo-oxygen redox conditions (Nicole *et al.,* 2013).

Extreme temperature fluctuations, which are earlier, confined to specific niche and clusters are now distributed widely across the globe. Mother Earth reacts to these shifts heterogeneously and there is neither any generality, nor they are limited to a particular area. Holocene abrupt cooling events are studied to defend the rapid changes, which may reappear in the near future (Park *et al*., 2019). After the end of Younger Drias, the important Holocene change was a rapid climate cooling occurred about 8200 years ago (Richard and Anna, 2005). Particularly, the Younger Dryas has disturbed the northern hemisphere which brought generally cold and dry conditions alternatively in the winter time. The cooling event of 8.2 ka have also been identified from the northern Indian Ocean environment, however the continental counter part of the cooling event from the Indian landmass was not well established. Globally, at a time period of 4.2 ka, a dry climate prevailed both in marine as well as continental records (Banerji *et al.,* 2020). Ostracoda biodiversity and species composition vary concerning the climate and address these changes in the ecosystems (Thomas *et al.,* 1999). The elemental reading of biogenic carbonate is used in understanding paleoenvironment (Bernd *et al.,* 2010). A vivid and diverse environmental behaviour prevails in different regions in Bay of Bengal (Mohammed *et al*., 2017). Salinity, temperature, nature of sediments and depth of the water column affects the distribution of Ostracoda species (Noohu *et al.,* 2019). Element to calcium partitioning of Mg, Sr, Fe and U is an indicator of temperature, salinity, oxygenation and organic matter decay (Nicole *et al.,* 2013). The examination of Mg and Ca in marine Ostracoda shells by electron microprobe and laser ablation analysis reflects on the non-homogenous Mg and Ca distribution in the shells. Besides, the different species have varying shell element

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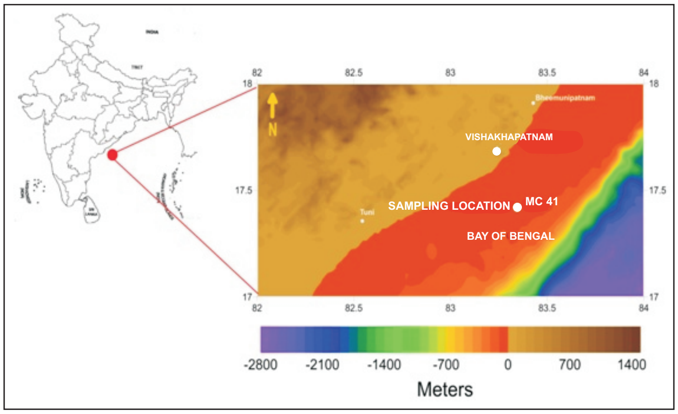

Fig.1. Study area map with sampling location

composition, possessing a poorly calcified epicuticle with enriched Mg (De Deckker, 2017).

With an objective to address the paleothermometric fluctuations, Ostracoda valves are scrutinized from shallow core sediments of off-Visakhapatnam, the Bay of Bengal (ORV Sagar Kanya Cruise SK-308 Leg 1 fieldwork, at a water column depth of 73 m; 17.419 N and 83.344 E, latitude and longitude respectively, the sediment core code MC 41, Fig.1.).

Materials and Methods

A shallow short sediment core of length 36cm retrieved from water column depth 73 m (core MC 41) was taken for the paleontological analysis and interpretations using a multi-corer during the ORV Sagar Kanya Cruise. Thirty-six subsamples (1cm interval) were done from the sediment core and wet sieved (ASTM 230) for recovering the Ostracoda species *i.e. Actinocythereis scutigera* (Brady, 1868) and *Bairdoppilata (Bairdoppilata) alcyonicola* (Maddocks, 1969). SEM images and the EDX studies were incorporated on the microfaunal specimens for illustration and elemental analysis. The species were studied for morphometric measurements and imaging in TESCAN VEGA 3 LMU, variable pressure analytical SEM with a resolution of 2 *nm*. The estimation of the elemental weight percentage of Ca, Mg, Ba, Sr, Fe, Mn and U in the Ostracoda valves are worked out with LN2-free microanalysis technique EDS (QUANTAX 200 with XFlash 6/30 SDD Detector) from Bruker energy solutions. Element to calcium partitioning was performed to assess the paleothermometric variations.

Ostracoda Genealogy

Two dominant species from the short core MC 41, *A. scutigera* and *B. (B.) alcyonicola* from different water depth have taken for elemental mapping, to infer the paleotemperature fluctuations.

Ostracoda species *B. (B.) alcyonicola* and *A. scutigera* (Fig. 2.) belong to Order Podocopida. *B. (B.) alcyonicola* is taxonomically grouped under the Suborder Bairdiocopina, Superfamily Bairdioidea and Family Bairdiidae. Taxonomic classification of *A. scutigera* is under Suborder Cytherocopina, Superfamily Cytheroidea and Trachyleberididae Family. Both the genera exhibit some specific and distinguished morphological traits that help in the identification.

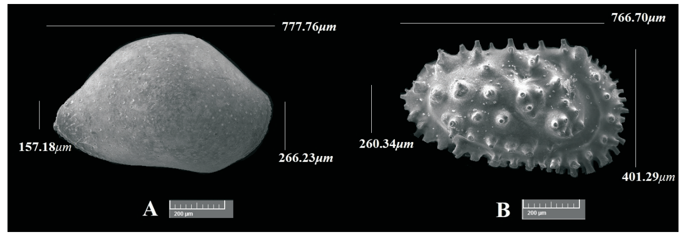

Fig.2. A: *Bairdoppilata (Bairdoppilata) alcyonicola* (Maddocks, 1969), B: *Actinocythereis scutigera* (Brady, 1868)

Results and Discussion

Morphometrical Measurements

Ostracoda morphometry can be used as a marker indicator for paleoenvironmental studies (Noohu *et al.*, 2021). Ostracoda are ecologically important and their distribution and diversity varies with the changes in salinity, temperature, substrate and depth (Hussain *et al.,* 2009). The shape variation accounts for the environmental changes and could use to access ecological as well as paleoecological characters (Claudia *et al*., 2018). For convenience of interpretation *B. (B.) alcyonicola* from the core depth 0-3 cm is termed as BA1 and *B. (B.) alcyonicola* from core depth 27-30 cm is referred as BA2. Similarly, *A. scutigera* at a depth of 0-3 cm is termed as AC1 and the same species at core 27-30 cm is referred as AC2. The morphometrical measurements of adult Ostracoda BA1 and BA2 in the area are having an average carapace length of 777.76 *µm* and 763.66 µm, with average carapace breadth of 299.95 µm and 324.67 *µm,* respectively. AC1 and AC2 are having an average anterior-posterior length of 766.70 *µm* and 763.66 *µm* with an average carapace breadth of 355.28 *µm* and 361.21*µm,* respectively. The specimens retrieved are whitish to creamy white, implying a normal supply of oxygen in the region. The observed valves are well preserved adults and the shells were opened because of the bacterial action and slower rate of the sedimentation. Fig.2. shows the SEM images of the recorded species. Spinose carapace of *A. scutigera* has higher Ca concentration and lower Mg and Sr values than the smooth carapace of *B. (B.) alcyonicola* which shows the morphological variations affect the trace element accumulation in the shells.

Elemental Mapping

Elemental mapping of the valves indicates that calcium accumulation is unique for the same species, irrespective of the depth of its occurrence. The calcium deposition in smooth form *B. (B.) alcyonicola* is more or less identical, except to the terminus portion. The ornamented *A. scutigera have* a higher concentration of calcium accumulation in the spines and raised regions than in the smooth area.

Calcium percentage concentration is 96.09%, 96.62%, 92.72% and 92.39% in AC1, AC2, BA1 and BA2, respectively. The elemental concentration of Mg, Sr, Ba, Fe, Mn and U were also determined. The elemental maps illustrated for Mg/Ca ratio (Fig.3) and the individual element percentage (Fig.4).

Paleothermometric Inferences

Mg/Ca and Sr/Ca concentration in Ostracoda shells from the

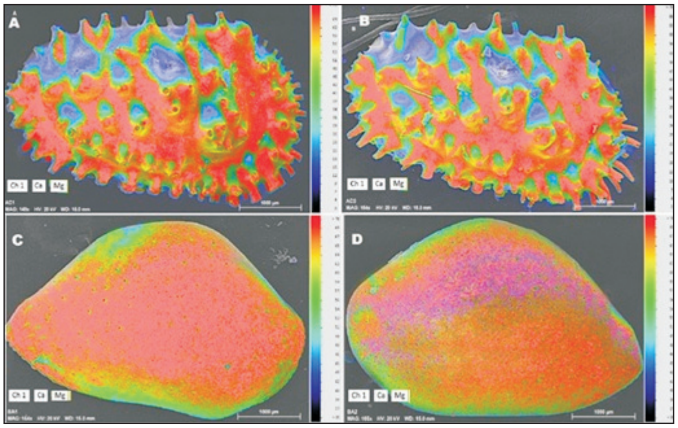

Fig.3. Mg/Ca mapping on A: *Actinocythereis scutigera* (0-3cm), B: *Actinocythereis scutigera* (27-30cm) C: *Bairdoppilata (Bairdoppilata) alcyonicola* (0-3cm), D: *Bairdoppilata (Bairdoppilata) alcyonicola* (27-30cm). (Scale 1000μm)

Gulf of Carpentaria is used for determining the paleoenvironment (DeDeckker *et al.,* 1988). Mg/Ca ratio shows proportionality with temperature (Stephan *et al.,* 2005). Sr/Ca ratio in Ostracoda shell is used for paleosalinity determination, U/Ca for oxygenation and Fe/Ca and Mn/Ca for determining oxygen-redox condition (Yair and Braddock, 2006; Borner *et al.,* 2013). Mg/Ca, Ba/Ca, Sr/Ca, Mn/Ca, Fe/Ca and U/Ca (Table 1) ratios are used as the proxies for finding the paleothermometric fluctuations, salinity and oxygen-redox condition. Elemental partitioning to calcium in Ostracoda shell were determined by calculating the ratio of elemental weight percentage in the shell to the atomic weight percentage of the element to have the values in mmol/mol and the obtained values are divided by Ca in mmol/mol and multiplied by 1000 to measure the ratio of element/calcium. U/Ca, Ba/Ca and Mg/Ca ratios have positive correlation; as the ratio of Mg/Ca becomes higher, the values of U/Ca and Ba/Ca are also having higher ratios and vice versa for the both species. Fe/Ca ratio is showing an indirect proportionality for U/Ca, Ba/Ca and Mg/Ca ratios. The value of Fe/Ca increases with a decrease in ratio of U/Ca, Ba/Ca and Mg/Ca. The upper part of the core shows a comparatively higher value of Mg/Ca in both the species and to the bottom core the ratio of Mg/Ca is slightly decreasing. At the top core, the species *B. (B.) alcyonicola* comparatively have a low Sr/Ca value (5.82 mmol/mol) with respect to the bottom core (8.42 mmol/mol). *A. scutigera*, comparatively have a higher ratio of Sr/Ca in the top core (2.38 mmol/mol) with respect to the bottom core (0.6 mmol/mol). Hence, the observation highlights that not in all species of ostracoda Sr/Ca and Mn/Ca ratios are in correlation with salinity. Different species behaves differently to the salinity fluctuations.

A lower Mg/Ca partitioning in the valve is an indicator of lower temperature in the region. However, in ostracoda from species to species the range of element/calcium values changes. This variability follows a similar pattern for Mg/Ca ratio in different species; in both the species the Mg/Ca values are decreasing to the bottom. The difference in the variation of Mg/Ca ratio in both the species is an indicator of the existence of temperature fluctuation in the geological past through the down core. The shell chemistry of ostracoda shows a seasonal oscillations in the element to calcium partitioning, which indicates a fluctuation in paleotemperature and changes in the paleoenvironmental condition. This shows that the area is dynamic and experienced a lot of environmental changes during the Holocene.

Table.1. Element to calcium partitioning in Ostracoda shells [AC1: *Actinocythereis scutigera* (0-3 cm), AC2: *Actinocythereis scutigera* (27-30 cm), BA1: *Bairdoppilata (Bairdoppilata) alcyonicola* (0-3 cm), BA2: *Bairdoppilata (Bairdoppilata) alcyonicola* (27-30 cm)]

Specimen	Mg/Ca	Ba/Ca	U/Ca	Fe/Ca	Sr/Ca	Mn/Ca
AC1	47.53	0.30	0.42	1.64	2.38	0.61
AC2	40.96	0.18	0.03	4.31	0.62	1.51
BA1	85.19	0.47	1.36	1.86	5.82	1.49
BA2	82.46	0.03	0.77	5.67	8.42	1.03

Values in mmol/mol

Conclusions

The congenial environmental condition of the area of deposition is gradually increasing with an increased supply of oxygen and is the reason for the increased productivity of ostracoda towards the top core. *A. scutigera* occurs in association with *B. (B.) alcyonicola* exhibit a mutual relationship and the downcore sediment analysis reveals that the productivity of both the microfauna is decreasing towards the bottom. However, in the zone with the increase of the number of *B. (B.) alcyonicola* the number of *A. scutigera* also increases and vice versa. The fauna retrieved are adult forms which can be understood by the morphometric measurements through which the calcium percentage of deposition is near unique for similar species throughout the core. The *B. (B.) alcyonicola has* a less concentration of Mg/Ca ratio in shell terminus at different depths, concerning other parts of the shell. The carapace of *A. scutigera is having* spinose structures with a high concentration of Mg/Ca ratio; whereas the flat area of the shells is having a low concentration of the same. Mg/Ca ratio in Ostracoda shell along with Ba/Ca ratio and U/Ca ratio display a unique pattern and indicating variations in depositional temperatures to downcore. Sr/Ca and Mn/Ca ratios are not showing any correlation and its distribution is random in the valves. The elemental partitioning to calcium varies for both the species. Mg/Ca ratio indicates a temperature difference exists through different depths of the core. However, a multi-proxy approach encompassing the proper quantification of ostracoda species in relation to temperature differences is needed for the more accurate interpretations of paleo-temperature.

Authors' Contributions

Mohammed Noohu Nazeer: Conceptualization, Investigation, Writing - original draft, Editing. **S.S Salaj:**

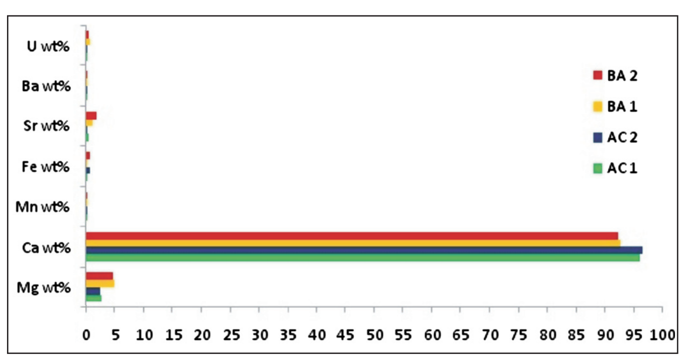

Fig.4. Individual element weight percentage in ostracoda shell

Visualization, and Investigation. **S.M. Hussain:** Supervision and Editing. **Dhanil Dev S.G:** Investigation, formal analysis. **S. Suresh Babu:** Reviewing and Editing, **N. Mohammed Nishath:** Methodology and Investigation.

Conflict of Interest

The authors have no competing or conflict of interest to declare. All the 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.

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References

Banerji, U.S., Arulbalaji, P., and Padmalal, D., (2020). Holocene climate variability and Indian Summer Monsoon: An overview. The Holocene, v. 30 (5), pp. 744-773

Bernd Schöne, R., Zengjie, Z., Dorrit, J., David Gillikin, P., Thomas, T., Dieter Garbe-Schönberg., Ted Mcconnaughey. and Analía, S., (2010). Effect of organic matrices on the determination of the trace element chemistry (Mg, Sr, Mg/Ca, Sr/Ca) of aragonitic bivalve shells (Arctica islandica)- Comparison of ICP-OES and LA-ICP-MS data. Geochem. Jour. ,v. 44, pp. 23-37.

Borner, N., Baere, B., De, Yang, Q., Jochum, K.P., Frenzel, P., Andreae, M.O. and Schwalb, A. (2003). Ostracod shell chemistry as proxy for paleoenvironmental change. Quatern. Int., pp. 1021. http://dx.doi.org/10/1016/j.quainy.2003.09.041.

Brady, G.S. (1868). Description of Ostracoda. *In*: D. Folin and Périer (*Eds.*), Les Fonds de la Mer. Part 1, pp. 49-112.

Claudia W., Thomas, A.N., Juliane, M., Maria, I.F., Ramos, and Werner, E.P. (2018). Significance of climate and hydrochemistry on shape variation- a case study on Neotropical cytheroidean Ostracoda. Biogeosciences., v. 15, pp.5489-5502.

De Deckker, P. (2017). Trace elemental distribution in Ostracoda valves. From solution ICPMS and laser ablation ICPMS to microprobe mapping: a tribute to Rick Forester. Hydrobiologia, v. 786, pp. 23-39.

De Deckker, P., Chivas, A.R., Shelley, J.M.G., and Torgersen, T., (1988). Ostracoda shell chemistry: a new palaeoenvironmental indicator applied to a regressive/transgressive record from the Gulf of Carpentaria, Australia. Palaeogeogr., Palaeoclimatol., Palaeoecol.,v. 66, pp. 231-241.

Hussain, S.M., Ravi, G., Mohan, S.P. and Rao, R. (2009). Distribution of Recent Ostracoda in the Bay of Bengal, Southeast Coast of India-Implication for Biodiversity. Gond. Geol. Magz., v. 24(1), pp. 35-39.

Maddocks, R.F. (1969). Revision of recent Bairdiidae (Ostracoda). U. S. Natl. Mus. Bull., v. 296, pp 1-126.

Mohammed, N.N., Hussain, S.M., Neelavnnan, K., Thejasino, S., Salim, S. and Rajkumar, A. (2017). Ostracoda biodiversity from shelf to slope oceanic conditions, off central Bay of Bengal, India, Palaeogeogr., Palaeoclimatol., Palaeoecol., v. 483, pp. 70-82.

Nicole, B., Bart De, B., Qichao, Y., Klaus, J., Peter, F., Meinrat, A. and Antje, S. (2013). Ostracoda shell chemistry as a proxy for paleoenvironmental change. Quat. Int., v. 313-314, pp. 17-37.

Noohu, M.N., Hussain, S.M., Salaj, S.S., Razi S. and Mohammed, N.N. (2021). Ostracoda morphometry in deciphering the paleo-environment of epipelagic to bathypelagic zone, off Visakhapatnam, Bay of Bengal. Jour. Geosci. Res., v.6 (1), pp.87-93.

Noohu, M.N., Radhakrishnan, K., Hussain, S.M., Sivapriya, V. and Rajkumar, A. (2019). Genus Krithe (Ostracoda) as a Proxy to Decipher Paleoceanography: A Global Review of the Genus, Mini review, Ocean Fisher. Acc. Jour., v. 10 (3), pp. 001-003.

Park, J., Jinheum, P., Sangheon, Y., Jin, C. K., Eunmi, L. and Jieun, C. (2019). Abrupt Holocene climate shifts in coastal East Asia, including the 8.2 ka, 4.2 ka, and 2.8 ka BP events, and societal responses on the Korean peninsula. Sci. Rep., v.9, pp. 1-16.

Richard, A. and Anna, A. (2005). The 8 K event: Cause and consequences of a major Holocene abrupt climate change. Quat. Sci. Rev., v. 24, pp. 1123–1149.

Stephan, B., Isabel, C., Heather, B. and Kazuyo, T. (2005). Planktonic foraminiferal Mg/Ca as a proxy for past oceanic temperatures: a methodological overview and data compilation for the Last Glacial Maximum. Quat. Sci. Rev., v. 24. pp. 821-834.

Thomas, C.M., Dawn DeMartino, M., Gary Dwyer, S. and Julio, Rodriguez-Lazaro (1999). Deep-sea Ostracodae species diversity: response to late Quaternary climate change. Mar. Micropaleontol., v. 37,pp. 231-249.

Yair, R. and Braddock, L. (2006). Mg/Ca and Sr/Ca Paleothermometry from calcareous marine fossils. The Encyclopedia of Quaternary Sciences, Elsevier Ltd., pp. 871-883.