Comparison of Total Phosphorus Contents and Total Alkalinity in Seawater of Different Area in the Bay of Bengal

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Abstract

Total phosphorus and total alkalinity at different depth throughout the water column (400 m depth, salinity ca. 34 psu) in three areas of the Bay of Bengal were investigated in order to compare their distribution in different areas of the Bay of Bengal. It was found that pattern of depth profile of both total phosphorus and total alkalinity in area C (the Andaman Sea) is different from the other two areas of the Bay of Bengal. Together with the relationship between total alkalinity and total phosphorus, it can be indicated that the characteristics of seawater in the enclosed Andaman Sea are different from the entire Bay of Bengal. In comparison with the other two areas, lower total alkalinity in the surface water and higher total alkalinity but lower total phosphorus in the deeper water was observed in the Andaman Sea.

Key words: total phosphorus, total alkalinity, Bay of Bengal

Introduction

Primary producer in the sea, phytoplankton, require dissolved inorganic nutrients for their growth. The free orthophosphate ion component is a vital nutrient for sustaining marine productivity (e.g., Codispoti, 1989; Tyrrell, 1999). It is well known as the limiting nutrient for primary productivity in marine systems. Regeneration of phosphorus from both particulate and dissolved forms of organic phosphorus is a potentially important source of bioavailable P for marine primary and secondary producers (Ammerman and Azam, 1985; Bjorkman and Karl, 1994; Jackson and Williams, 1985; Karl *et al*., 1993; Monaghan and Ruttenberg, 1999). Within pools of dissolved and particulate phosphorus or so-called total phosphorus, turnover rates of organic phosphorus are rapid and seasonal, enabling low inorganic phosphorus concentrations to support high primary productivity (Benitez-Nelson and Buesseler, 1999).

Total alkalinity, a measurement of buffering capacity of the marine systems, is known to be a conservative parameter of water masses, therefore its measurements act as a water mass tracer (Schiettecatte *et al*., 2003, Watanabe *et al*., 2004). However, the oceans act as a natural reservoir for carbon dioxide (CO_2). Atmospheric CO_2 dissolves naturally in the ocean, forming carbonic acid (H_2CO_3), a weak acid. It is estimated that the world ocean is taking up 1.7 GtC per year, which is almost 30% of the CO_2 released anthropogenically into the atmosphere (Prentice *et al*., 2001). The uptake of anthropogenic carbon since 1750 has led to the ocean becoming more acidic, with an average decrease in pH of 0.1 units (UNEP, 2008).

Although the coastal ocean is only a small fraction (8%) of the total ocean area, several studies have suggested the importance of the CO_2 dynamics in this area. Between 15% and 50% of the oceanic primary production is now attributed to coastal ocean (Walsh, 1991; Muller-Karger, 2000). Recent studies have concluded that some continental shelves, in general the zone shallower than 200 m, act as a sink for atmospheric CO_2 (Tsunogai *et al.*, 1999; Frankignoulle and Borges, 2001), of up to 0.6 GtC per year worldwide (Yool and Fasham, 2001), which is about 30% of the oceanic CO_2 uptake. Another reason that we care about alkalinity is that when organisms build calcium carbonate skeletons, they effectively remove calcium and carbonate from the water column. Progressive acidification of the oceans due to increasing atmospheric CO_2 is expected to reduce biocalcification of the shells; bones and skeletons most marine organisms possess (UNEP, 2008).

In this study, total phosphorus and total alkalinity at different depth throughout the water column (400 m depth, salinity ca. 34 psu) in three areas of the Bay of Bengal were investigated in order to compare their distribution in different areas of the Bay of Bengal.

Material and Methods

Sample collection was conducted onboard M.V. SEAFDEC from 25 October to 21 December 2007 under an Ecosystem-Based Fishery Management Project in the Bay of Bengal in collaborative among the BIMSTEC members (Bangladesh, India, Myanmar, Nepal, Sri Lanka, and Thailand).

Seawater samples were collected at selected depth, using a iCTD system couple with Carousel water sample (Niskin Bottles), from 28 oceanographic stations in the Bay of Bengal 12 stations in area A (upper part of the Bay of Bengal covered international waters and the EEZ of Bangladesh and India), 4 stations in area B (western area of the Bay of Bengal, offshore of India and Sri Lanka waters) and 12 stations in area C (central part of the Andaman Sea covered the EEZ of Myanmar and the Andaman Island of India) (Fig. 1).

Sea water samples for total phosphorus analysis were filled in pre-cleaned 60 ml plastic bottles and immediately kept frozen (-45ºC) until analyzed. Sea water samples for total alkalinity analysis were filled in 125 ml plastic bottles which pre-added a few drops of $HgCl_2$ and then store at room temperature until analysis.

Since total phosphorus defined as all forms of phosphorus, all bound fractions were liberated by persulfate oxidation prior the measurement of the orthophosphate form by ascorbic acid-colorimetric method (Menzel and Corwin, 1965; Grasshoff *et al.*, 1983; Strickland and Parsons, 1972)

The amount of total alkalinity in seawater was measured by carrying out a potentiometric titration of a known volume of sea water in a vessel which is sealed from the atmosphere. This is accomplished by adding precise amounts of 0.1 N HCl to the vessel in small increments, and measuring the change in the electromotive potential of the water caused by this addition. The data were used to calculate the total alkalinity by the modified Gran method.
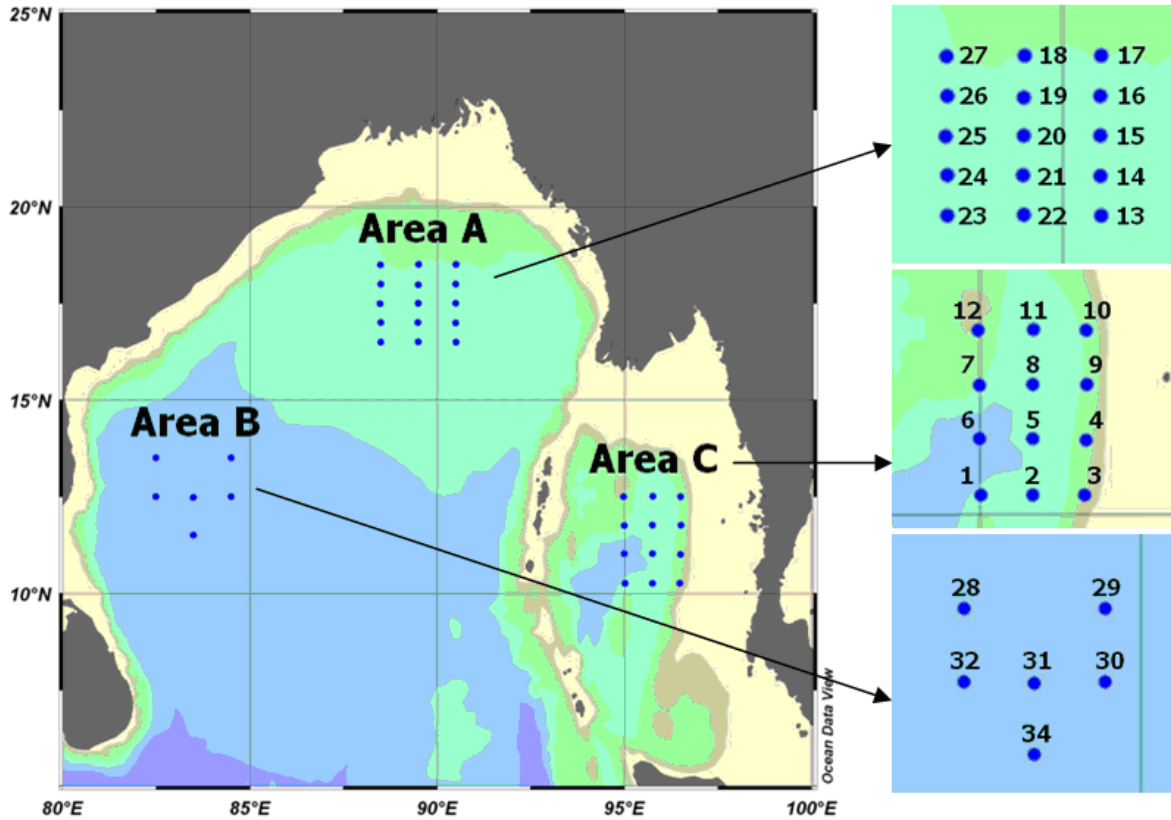
Figure 1 Location map of seawater sampling sites in the Bay of Bengal there was no water sampling in the EEZ Indian waters of area A and B (stations 25, 26, 27, 28 and 32).

Results and Discussions

Vertical profiles of total phosphorus concentration and total alkalinity values at various depths of the sampling stations in the different area of the Bay of Bengal are presented in fig. 2 and 3, respectively. The average (± standard deviation), minimum and maximum values of total phosphorus and total alkalinity at various depths of different area in the Bay of Bengal are presented in tables 1 and 2, respectively.

The results showed an increasing of total phosphorus and total alkalinity with depth to about 100 m depth, and then both values remain fairly constant. Average total phosphorus was found to be the lowest in surface layer (above 100 m) of the Andaman Sea (Figs. 2 and 4). High variation of total alkalinity was found throughout the water column in the Andaman Sea, while the total alkalinity of deeper water (below 100 m) of areas A and B were relatively constant (Fig. 3). The lower values and high variation of total alkalinity in surface water of areas A and C (Fig. 3) indicated an influence of freshwater discharged to these coastal areas.
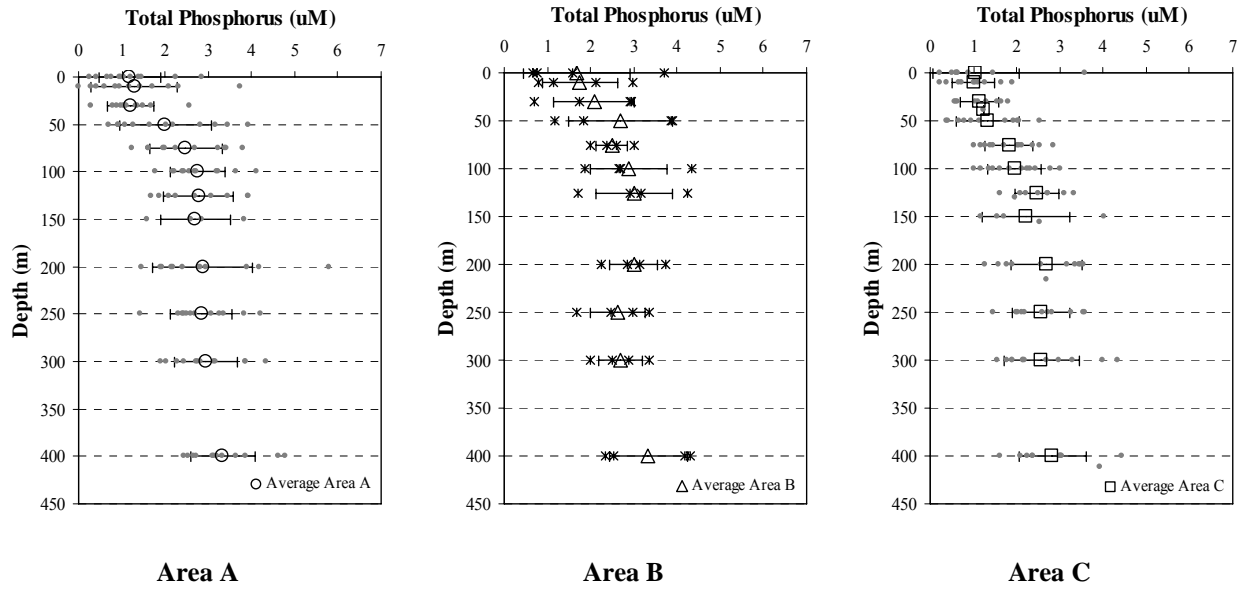
Figure 2 Vertical distribution of total phosphorus at each sampling stations (•), and average total phosphorus values (± SD) in area A (○), area B (△) and area C (□).
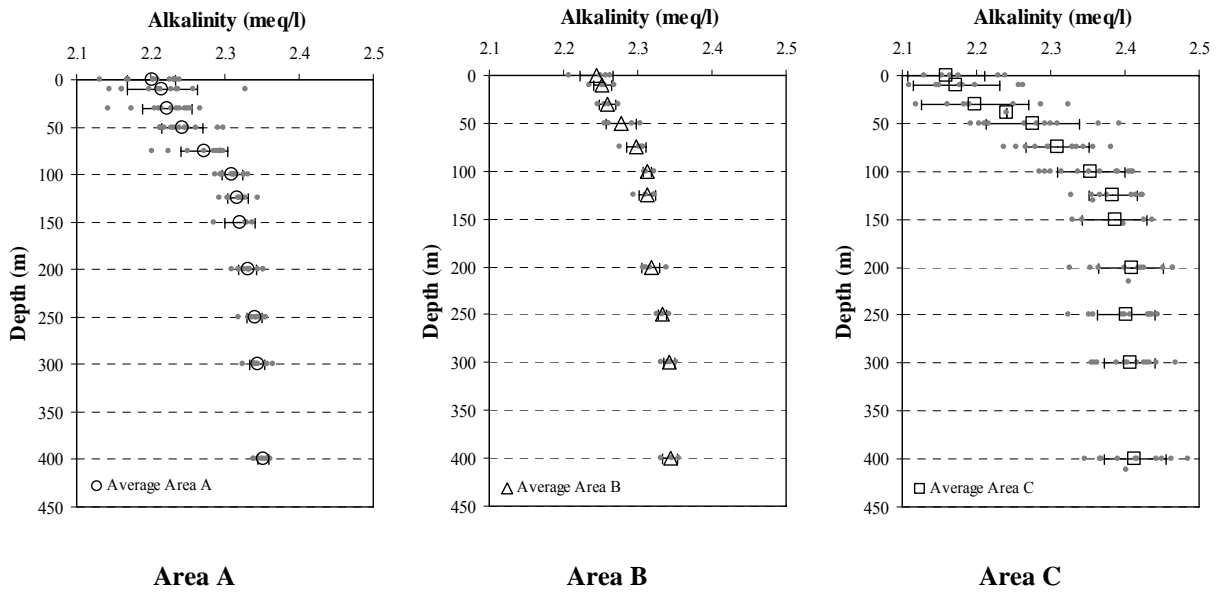

Figure 3 Vertical distribution of total alkalinity at each sampling stations (•), and average total alkalinity values (± SD) in area A (○), area B (△) and area C (□).

Table 1 Average concentration of total phosphorus (μM) in different areas of the Bay of Bengal (average±SD).

Depth (m)	Area A		Area B		Area C	
	Average	Min.-max	Average	Min.-max	Average	min.-max
Surface	1.18±0.71	0.40-2.84	1.68±1.23	0.75-3.72	1.06±1.00	0.21-3.56
10	1.29±1.00	0.005-3.73	1.76±0.86	1.13-2.98	1.00±0.50	0.24-1.91
30	1.21±0.53	0.28-2.55	2.08±0.93	1.75-2.96	1.14±0.44	0.57-1.81
50	2.01±1.06	0.69-3.94	2.69±1.21	1.17-3.90	1.33±0.72	0.39-2.52
75	2.47±0.84	1.23-3.81	2.49±0.38	1.98-3.02	1.83±0.56	1.01-2.85
100	2.77±0.64	1.78-4.13	2.88±0.90	1.85-4.32	1.95±0.61	1.02-3.02
125	2.77±0.81	1.67-3.92	3.00±0.89	1.72-4.23	2.47±0.52	1.61-3.32
150	2.70±0.80	1.57-3.82	-	-	2.21±1.01	1.18-4.03
200	2.87±1.17	1.46-5.78	2.99±0.54	2.24-3.75	2.69±0.82	1.27-3.55
250	2.84±0.72	1.42-4.21	2.63±0.63	1.68-3.37	2.57±0.66	1.44-3.57
300	2.94±0.73	1.90-4.33	2.68±0.51	1.98-3.37	2.58±0.87	1.55-4.34
400	3.34±0.73	2.45-4.77	3.34±0.91	2.34-4.32	2.83±0.78	1.60-4.42

Table 2 Average concentration of total alkalinity (meq/l) in different areas of the Bay of Bengal (average±SD).

| Depth (m)	Area A		Area B		Area C	
	Average	min.-max	Average	min.-max	Average	min.-max
Surface	2.20±0.03	2.13-2.24	2.24±0.02	2.21-2.26	2.16±0.05	2.08-2.24
10	2.22±0.05	2.14-2.33	2.25±0.01	2.24-2.27	2.17±0.06	2.07-2.26
30	2.22±0.03	2.14-2.27	2.26±0.01	2.25-2.27	2.20±0.07	2.08-2.32
50	2.24±0.03	2.21-2.30	2.28±0.02	2.25-2.30	2.28±0.06	2.19-2.39
75	2.27±0.03	2.20-2.30	2.30±0.01	2.28-2.31	2.31±0.04	2.24-2.38
100	2.31±0.01	2.29-2.33	2.31±0.01	2.31-2.32	2.35±0.05	2.29-2.41
125	2.32±0.01	2.29-2.34	2.31±0.01	2.29-2.32	2.38±0.03	2.33-2.42
150	2.32±0.02	2.28-2.34	-	-	2.39±0.04	2.33-2.44
200	2.33±0.01	2.31-2.35	2.32±0.01	2.31-2.34	2.41±0.04	2.33-2.47
250	2.34±0.01	2.32-2.35	2.33±0.01	2.33-2.34	2.40±0.04	2.32-2.44
300	2.34±0.01	2.32-2.36	2.34±0.01	2.33-2.35	2.41±0.03	2.35-2.47
400	2.35±0.01	2.34-2.36	2.34±0.01	2.33-2.36	2.41±0.04	2.35-2.49
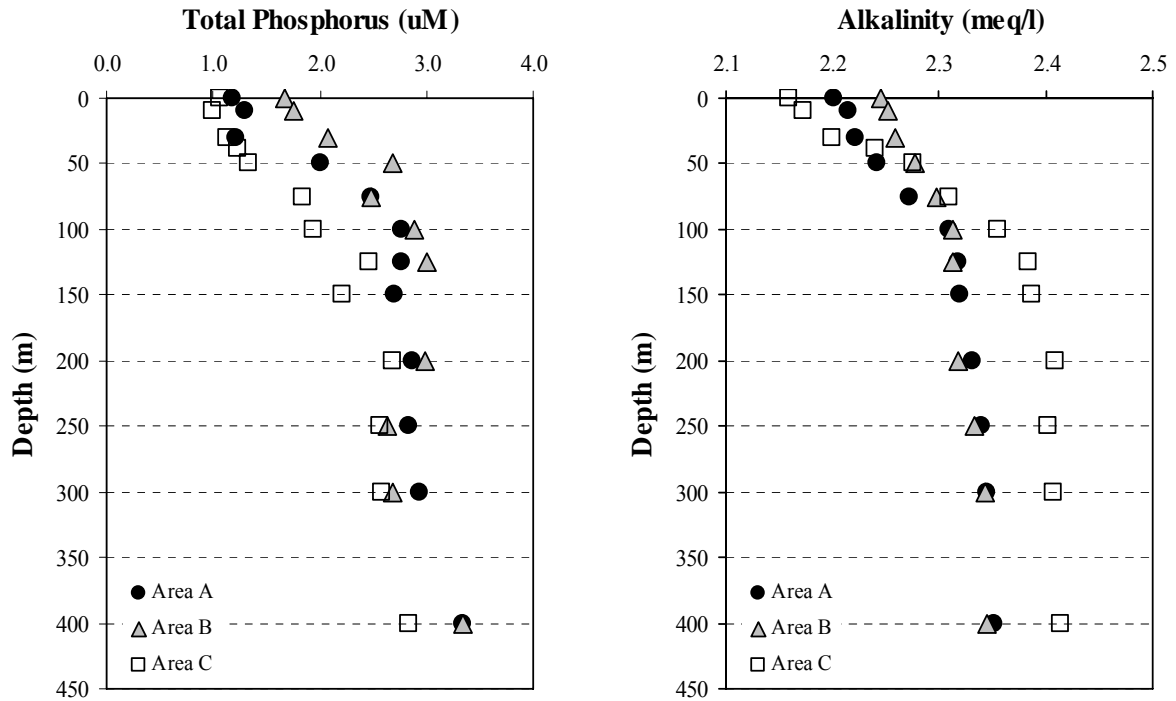
Figure 4 Comparison of average total phosphorus (left) and average total alkalinity (right) depth
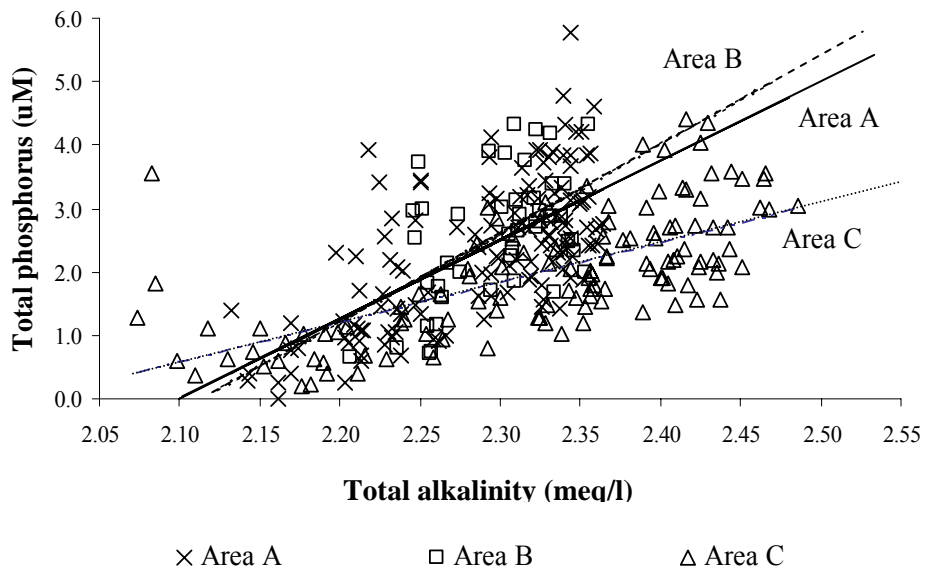profiles from different area in the Bay of Bengal.

Figure 5 Total phosphorus with total alkalinity relationships in the three study areas in
the Bay of Bengal.
(Each individual line represents the trend of each area)

It is clearly seen in fig. 4 that the characteristics of the Andaman seawater is
differentiated from the entire Bay of Bengal by having low total phosphorus and low total
alkalinity in surface water and high total alkalinity in deeper water. The relationships between

total phosphorus and total alkalinity of samples taken from area A and B give similar trend lines, whereas those from area C (the Andaman Sea) show a dissimilar trend (Fig. 5). High variation of total alkalinity values throughout the water column down to 400 m depth in the Andaman Sea may be affected from internal waves. It is believed that the internal waves in the Andaman Sea occur all year round (Jackson, 2004). The amplitudes of internal waves in the Andaman Sea may be up to 70-80 m and can propagate over several hundred kilometers, which lead to transport of water mass and induce turbulence and mixing in the water column (Osborne and Burch, 1980; Jackson, 2004).

Fig. 6 and 7 illustrate horizontal distribution of total phosphorus and total alkalinity, respectively, at different depth. These two figures indicate that the eastern part of the Bay of Bengal is a low total phosphorus region. The distribution of total alkalinity and total phosphorus along north-south section in the area C (the Andaman Sea) and area A (the upper part of the Bay of Bengal) are illustrated in figs. 8 and 9, respectively, and the east-west section of area A is shown in fig. 10.

Conclusion

The total alkalinity in surface water of area C (the Andaman Sea) is lower than those of areas A and B, however, but is higher at the depths below 100 down to 400 m. The vertical distribution of total phosphorus and total alkalinity in areas A and B of the Bay of Bengal are similar. The differentiated pattern of depth profiles of both total phosphorus and total alkalinity together with the relationship between total alkalinity and total phosphorus indicate that sea water characteristics in the enclosed Andaman Sea is different from the entire Bay of Bengal.

Unfortunately, analyses of organic carbon and total nitrogen in these seawater samples are not yet finished. Total alkalinity coupled with pH and temperature data, amount of dissolved inorganic carbon (DIC) species and dissolved carbon dioxide gas (pCO$_2$) in seawater can be calculated. Interpretation of this data set will provide clearer understanding of biogeochemical processes occurring in these three areas of the Bay of Bengal.
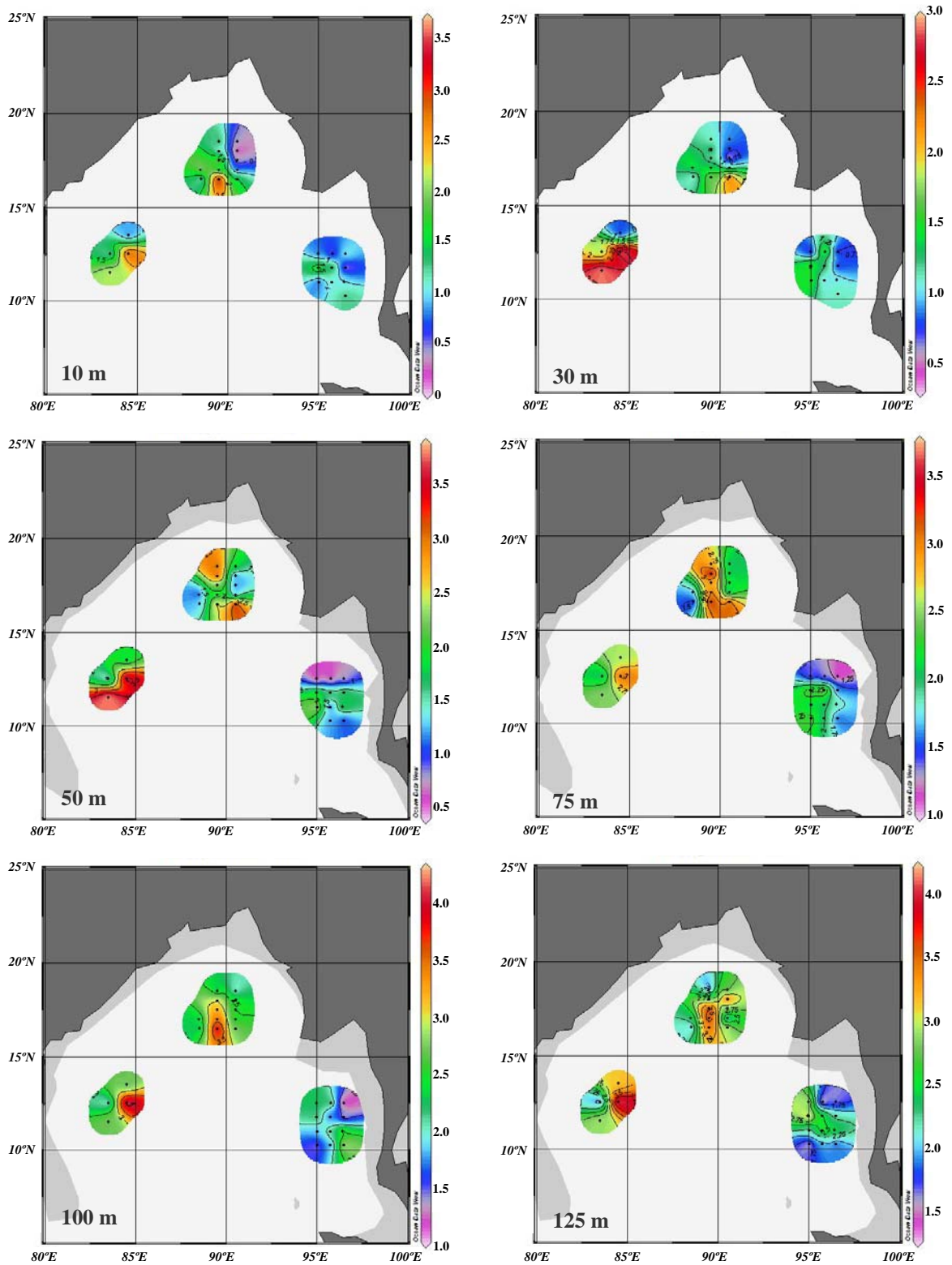
Acknowledgement

Figure 6 Horizontal distribution of total phosphorus (μM) at 10, 30, 50, 75, 100, 125, 200, 250
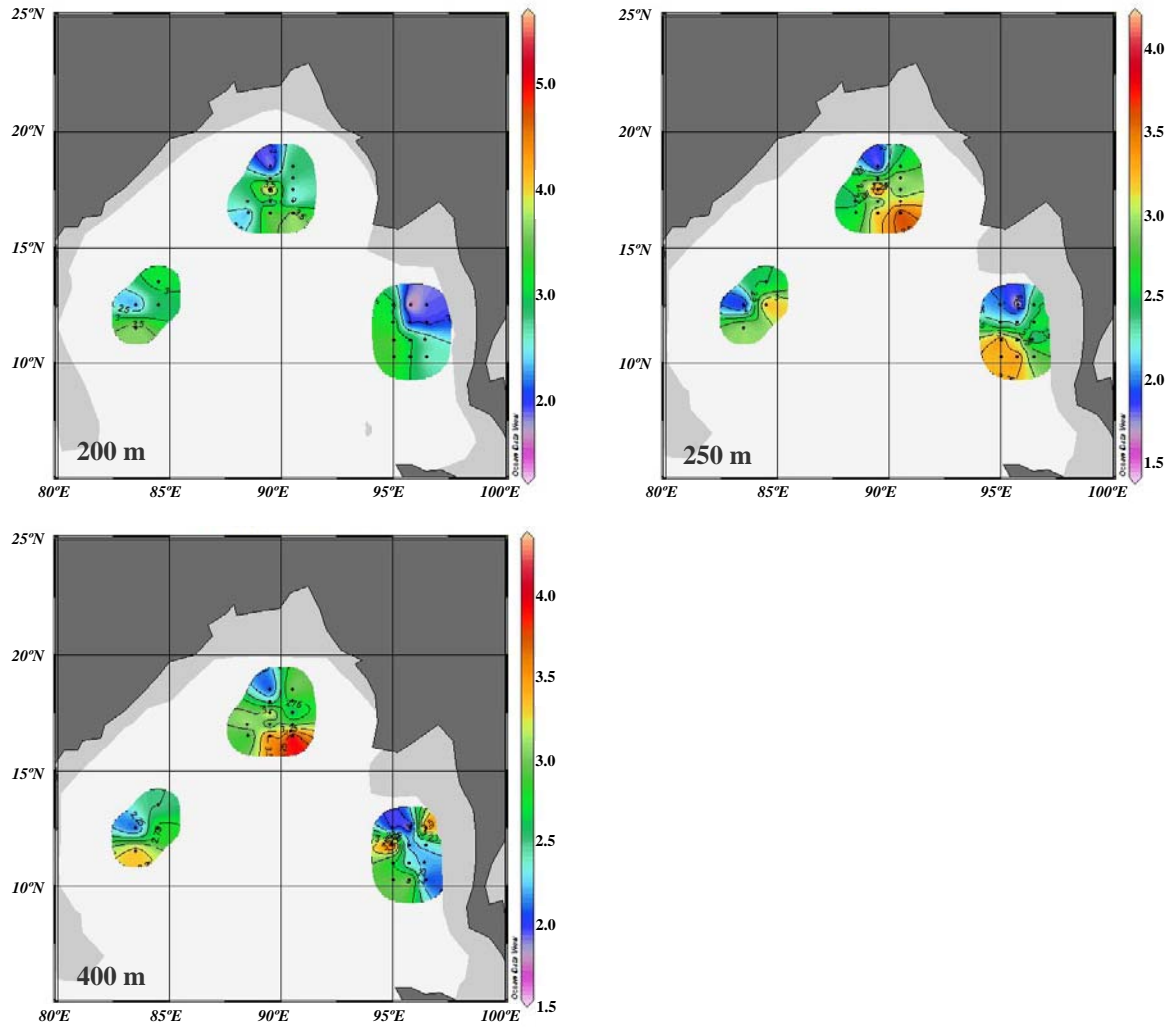and 400 m depth.
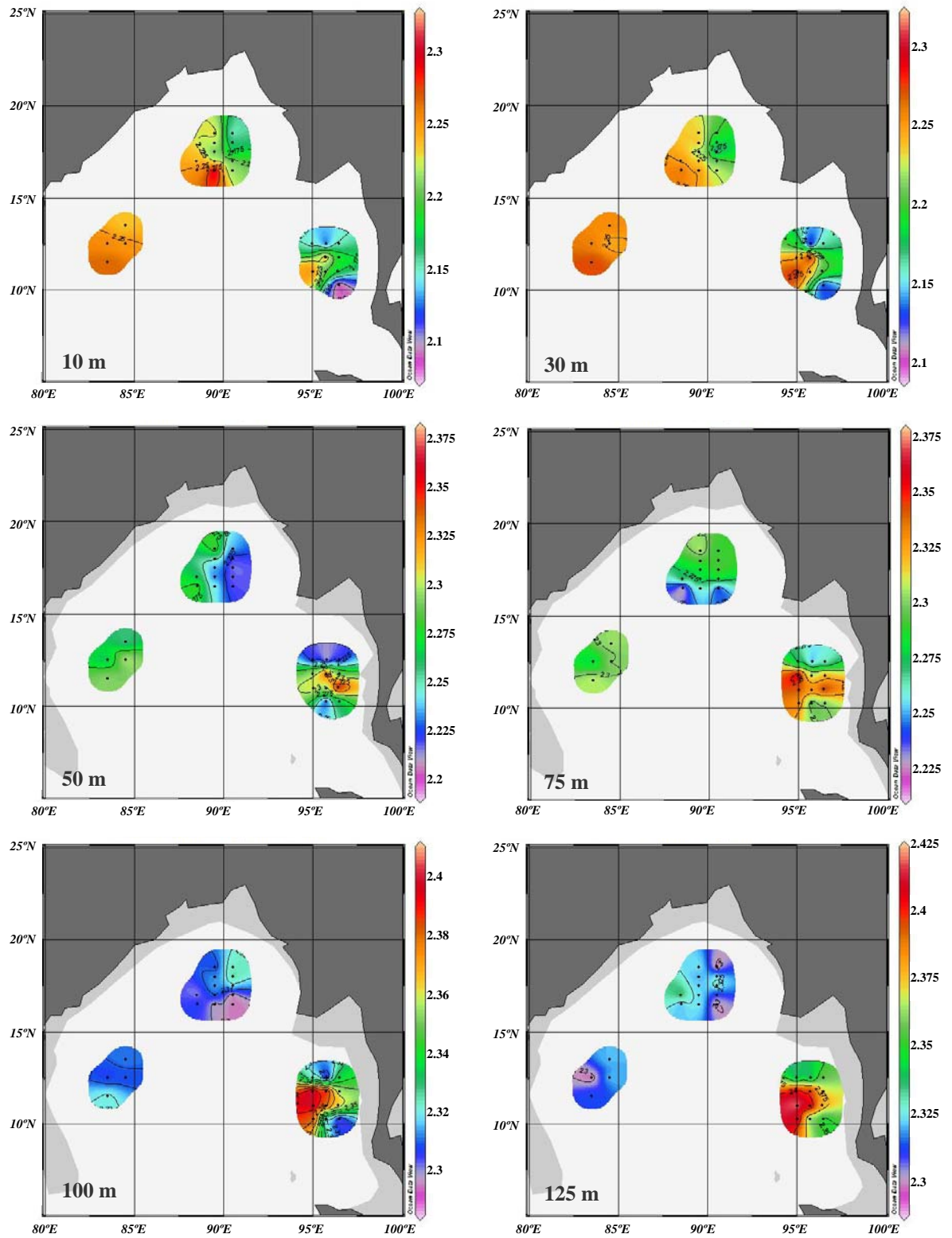
Figure 6 (cont.)

Figure 7 Horizontal distribution of total alkalinity (meq/l) at 10, 30, 50, 75, 100, 125, 200, 250 and 400 m depth.
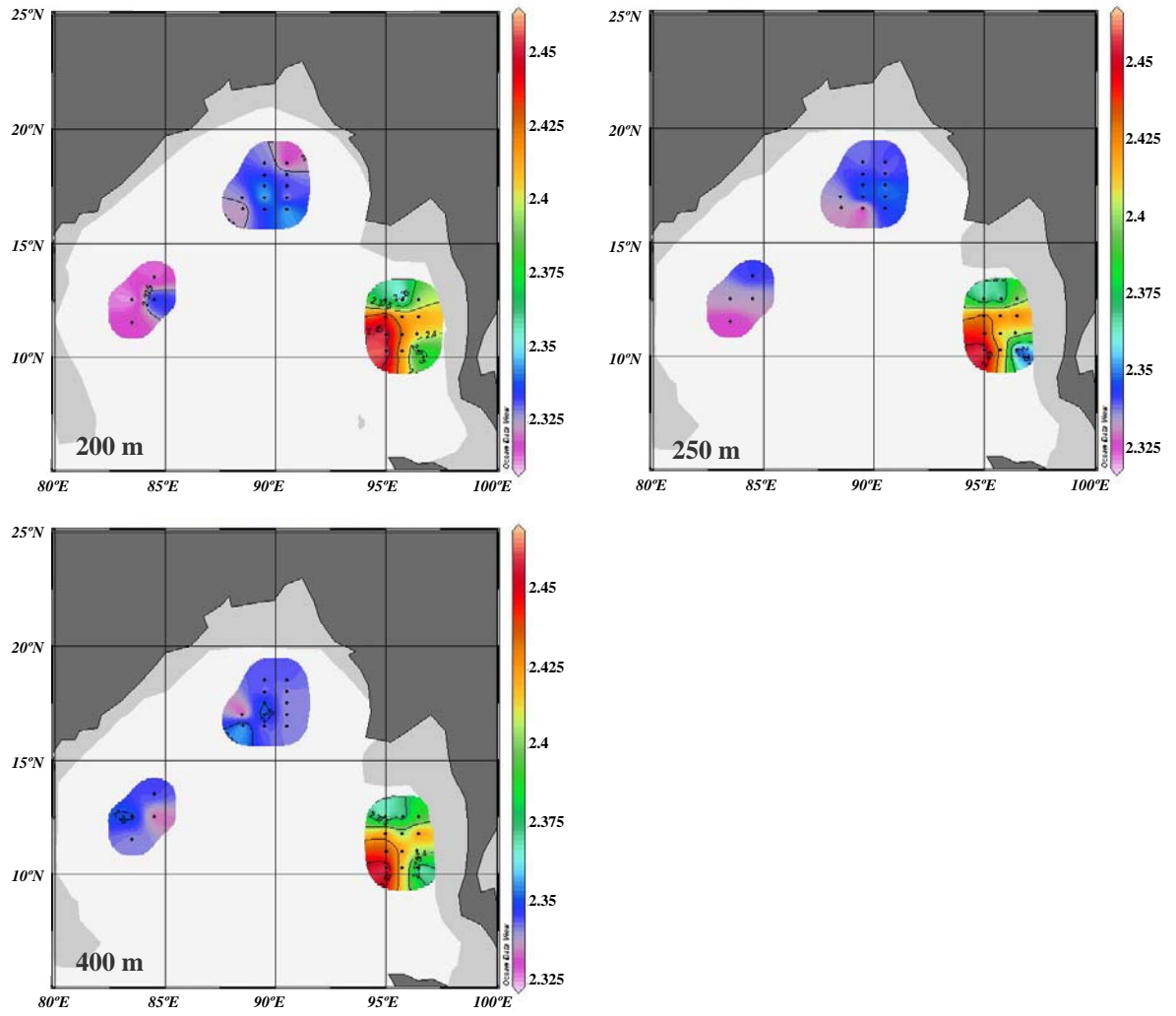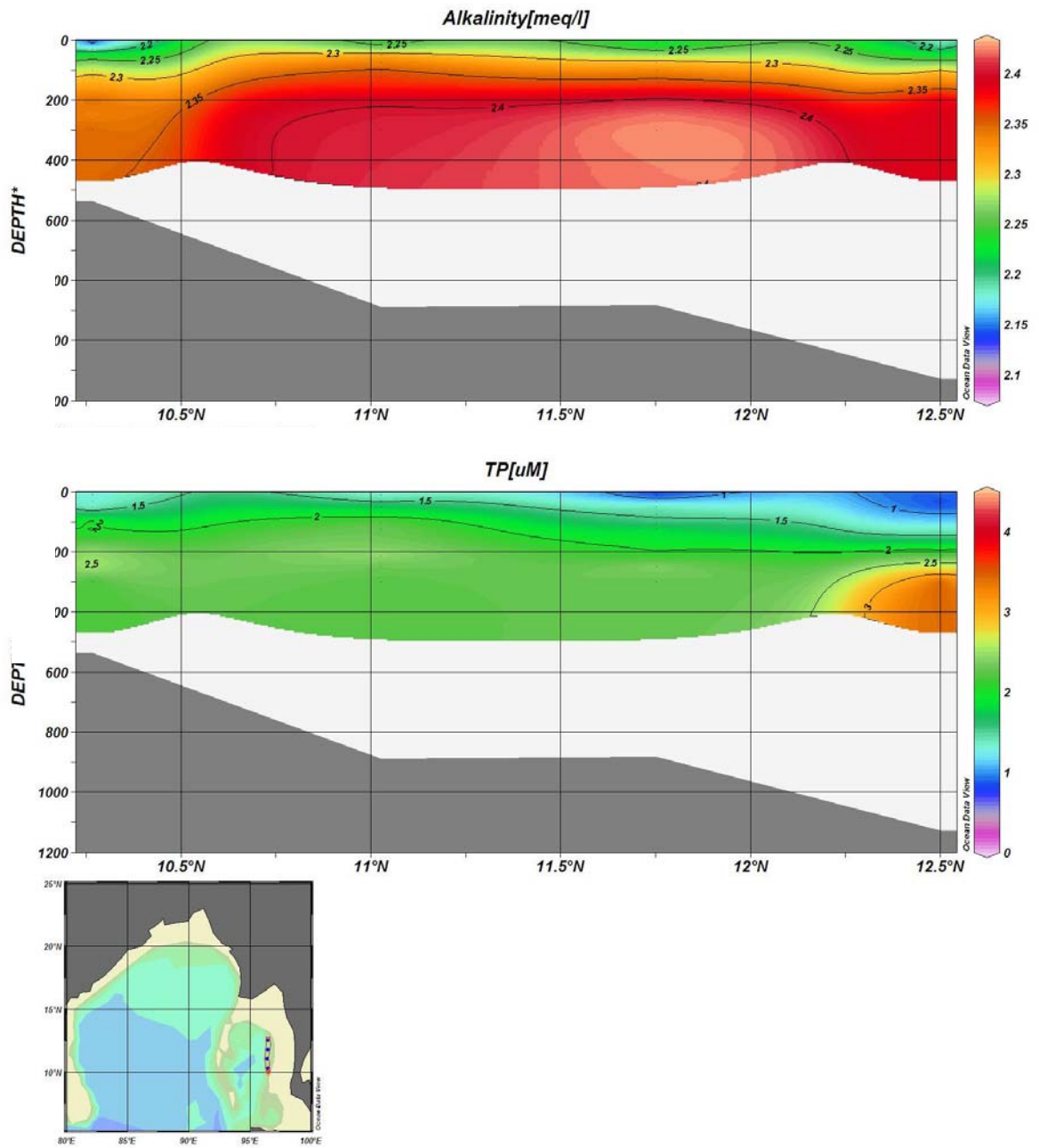
Figure 7 (cont.)

Figure 8 Distribution of total alkalinity (upper) and total phosphorus (lower) along N-S section in area C (the Andaman Sea).
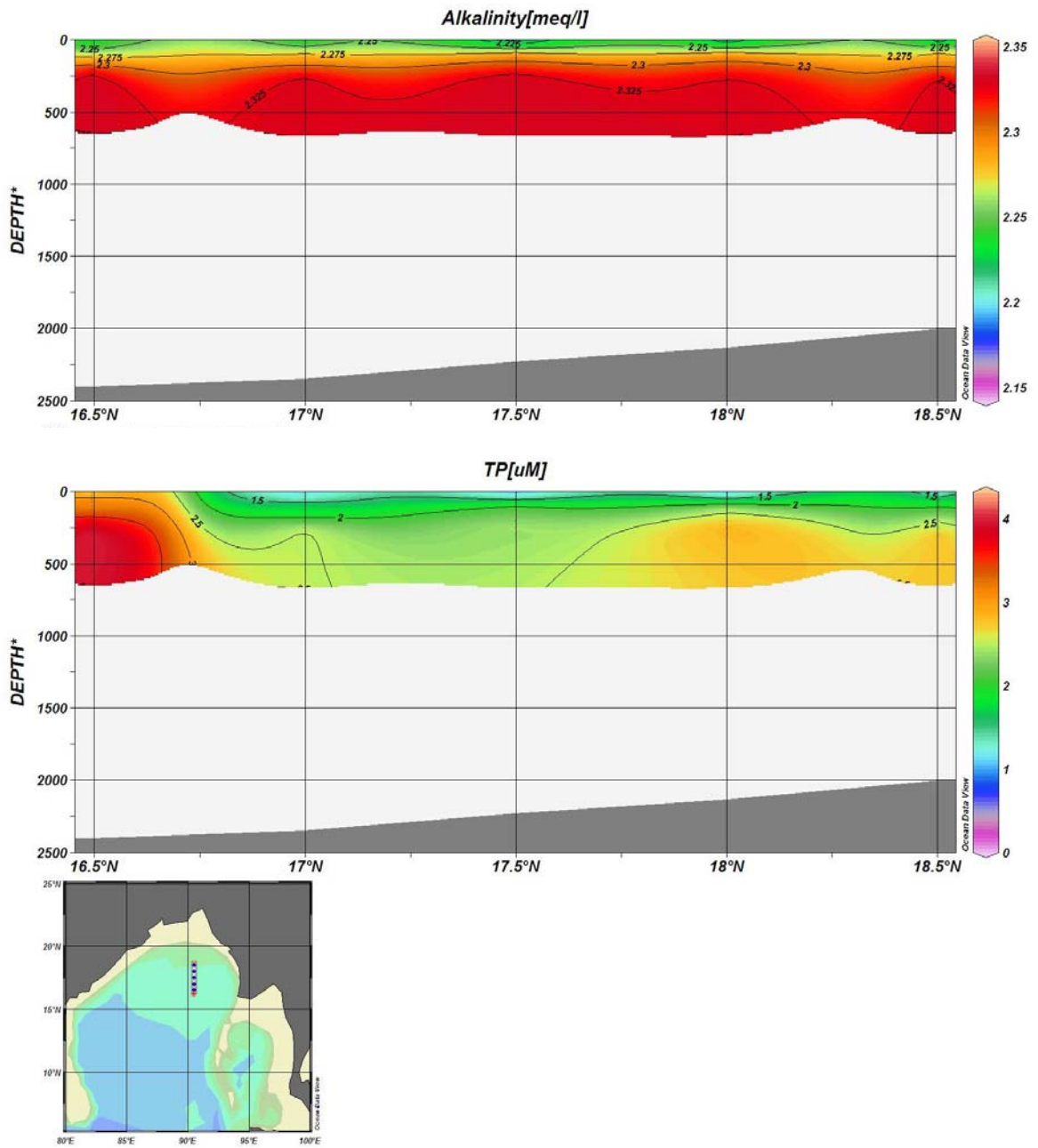
Figure 9 Distribution of total alkalinity (upper) and total phosphorus (lower) along N-S section in area A (the upper part of the Bay of Bengal).
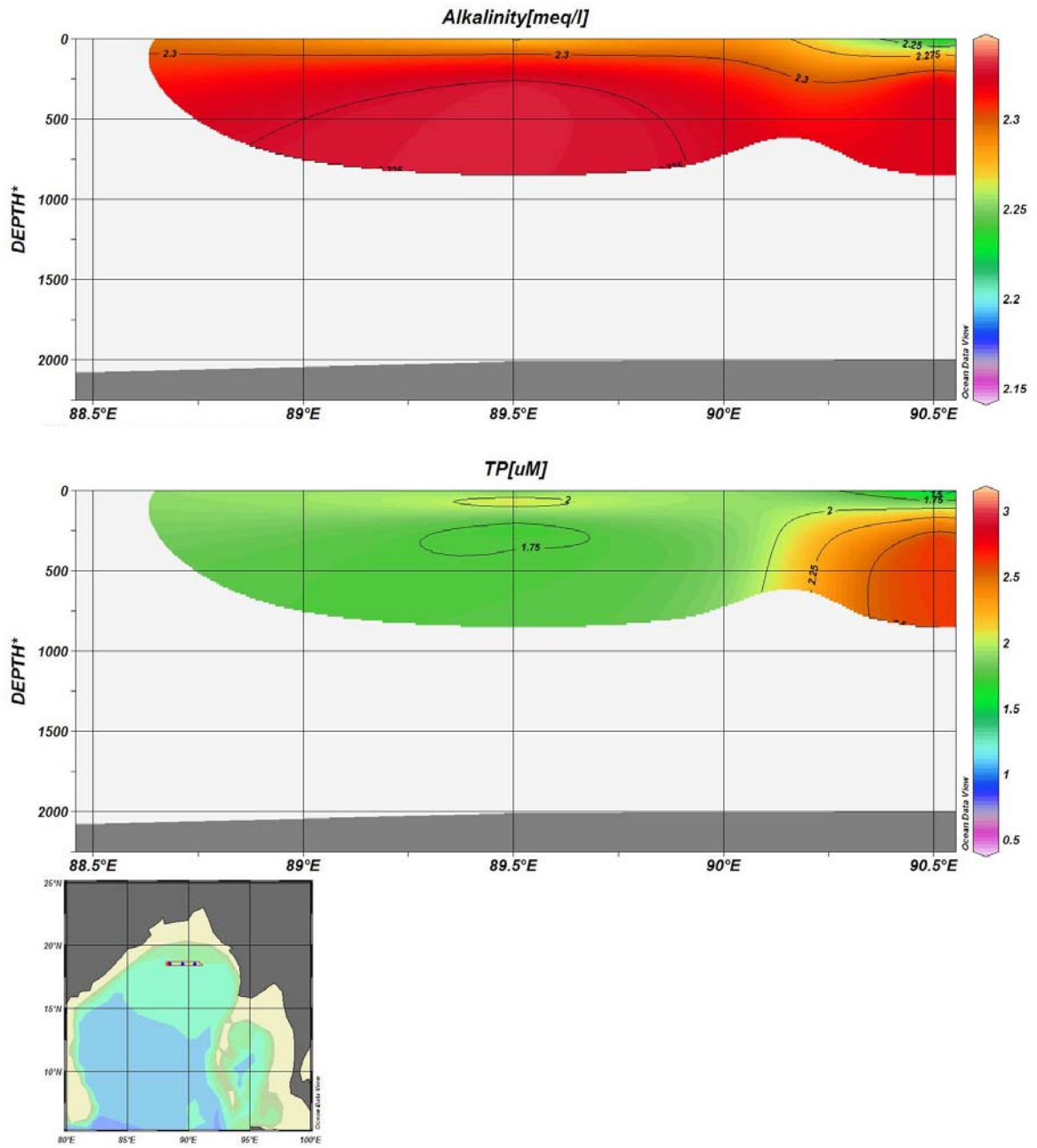
Figure 10 Distribution of total alkalinity (upper) and total phosphorus (lower) along E-W section in area A (the upper part of the Bay of Bengal).

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