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GEOCHEMISTRY OF PHOSPHORUS IN THE BOTTOM SEDIMENTS OF THE EASTERN PART OF BAY OF BENGAL*

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ABSTRACT

Investigations were carried out to understand the distribution of phosphorus and its relationship with some chemical constituents and biological aspects in the clay-sized bottom sediments of the eastern part of Bay of Bengal collected during a cruise on "Anton Brunn" in 1963. Concentration of phosphorus varies regionally in these sediments with a significant increase from north to south. The increase in the phosphorus content with decreasing iron content in the clayey sediments does not support the probable fixation of phosphorus as ferric phosphate. The sympathetic relationship of phosphorus with calcium and the presence of calcareous material strongly suggest the possible fixation of the phosphorus as calcium phosphate. Both phosphorus and organic matter contents are low in the northern part, where there is abundance of river-borne terrigenous material. This indicates that phosphorus is not brought from the continental source in notable amounts. It is inferred that the increase in phosphorus content in the southern part is due to high planktonic production and lack of continentally derived terrigenous matter and that the phosphorus here is mostly biogenic in origin.

INTRODUCTION

THE process of concentration of marine phosphate is far from being well understood, though it has been the subject of investigation by several workers. Phosphorus may be tied-up in compounds like ferriphosphate and calcium phosphate. It is also one of the essential constituents of living organisms. Usually, in a marine environment, the organic productivity depends on the presence of nutrients such as silicates, phosphates and nitrates. Therefore it is the accepted view of most of the oceanographers that the bottom sediments act as reservoirs of the nutrients. The present study deals with the distribution of phosphorus in the clay-sized (less than 4 micron size) marine sediments of the eastern part of Bay of Bengal (Lat. 7°40′–20° 28°′ Long. 92° 20′ – 97° 59′) in relation to some chemical constituents and biological aspects.

Very little is known regarding the concentration of total phosphorus in sea-water except through the investigations of Kalle (1935), Armstrong and Harvey (1950), Cooper (1951), Bush *et al.*, (1955) and Redfield *et al.*, (1957). The available information on the distribution of phosphorus in the shelf sediments off the east and west coasts of India is rather limited and is due to the work carried out by Seshappa (1953) and Seshappa and Jayaraman (1956) on the sediments in the inshore region of Calicut, by Shenoi (1960) on the sediments of the Kakinada Bay, by Siddiquie and Choudhury (1968) and Murty *et al.*, (1968) on the sediments off the west coast of India.

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SAMPLE COLLECTION AND METHODS OF ANALYSES

The samples used in the present investigation were collected during a cruise on "Anton Brunn", a U. S. Oceanographic ship, in 1963 under the leadership of E. C. La Fond as a part of International Indian Ocean Expedition. The sediments were collected by dredge and snapper.

In the laboratory each of the sediment samples was initially dispersed overnight in 0.01 N ammonia in long sedimentation jars and the Clay-sized sediment, (less than 4 microns) was decanted out after allowing the suspension to settle for two hours and three minutes (Krumbein and Pettijohn, 1938). The clay fraction thus separated was later dried. The quantitative estimation of total phosphorus as P_2O_5 has been carried out following the method of Rochford (1951). Iron was colorimetrically determined by the method of Snell and Snell (1949). The gravimetric method of Groves (1937) has been adopted for the estimation of calcium.

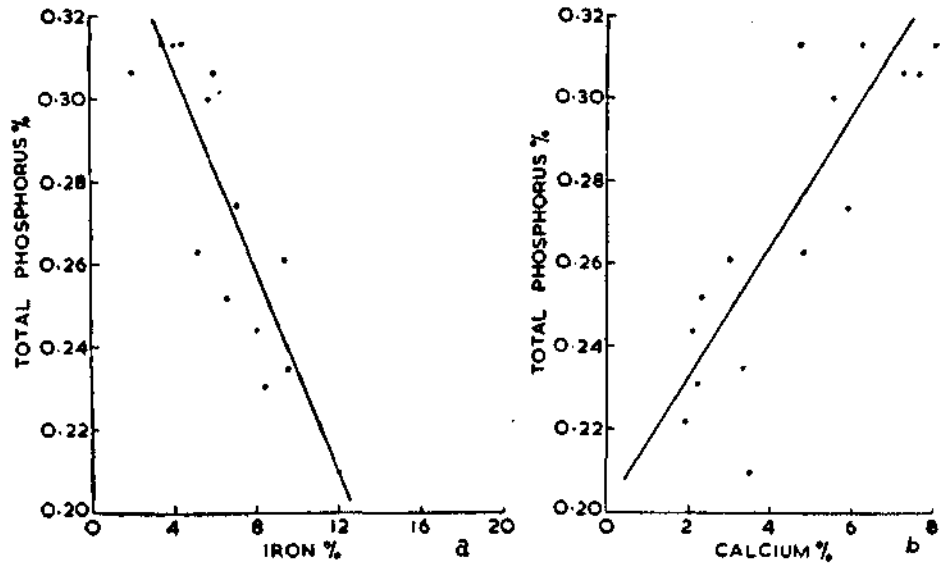

Fig. 1a. Scatter plot of total phosphorus versus iron, and b. Scatter plot of total phosphorus versus calcium.

RESULTS AND DISCUSSION

The percentage amounts of total phosphorus, calcium and iron in the clay-sized marine sediments of the eastern part of Bay of Bengal with their depth of collection are given in Table 1. The total phosphorus content varies from 0.21% to 0.31%. Generally, the phosphorus content increases from north to south. The average phosphorus concentration in these sediments (0.27%) is higher than the 0.15% of phosphorus given as an average of deep-marine clays (Turekian and Wedepohl, 1961). However, this value is nearer to the average value of phosphorus in the sediments of west coast of India (Siddiquie and Choudhury, 1968) and the western part of Bay of Bengal (Rao and Rao, 1970). Hirst (1962) has reported a value of 0.137% phosphorus for the modern sediments of Gulf of Paria.

A scatter plot diagram of total phosphorus plotted against iron in the sediments shows a negative relationship between these two constituents (Fig. 1 a). A general increase in the content of iron has been observed towards north where the rate of deposition of land-derived material is high. This leads to the conclusion that the phosphorus contribution from adjacent land area through rivers is negligible and the phosphorus is not precipitated as ferriphosphate in the marine sediments of the eastern part of Bay of Bengal.

TABLE 1. *Total phosphorus, Iron, and calcium in the bottom sediments of the eastern part of Bay of Bengal*

Sample No.	Location	Depth in fathoms	Phosphorus %	Iron %	Calcium %
Southern Part:					
17	7°40′ N- 97°08′ E	202	0.3137	4.4	06.24
19	8°29′ N- 97°59′ E	27	0.3137	4.0	04.74
20	9°13′ N- 97°51′ E	35	0.3063	2.0	7.677
24	10°36′ N- 95°39′ E	1360	0.2100	12.0	3.518
28–I	11°20′ N- 92°40′ E	30	0.3007	5.7	5.505
28–II	11°35′ N- 92°40′ E	25	0.2316	8.33	2.238
28	11°49′ N- 92°52′ E	49	0.2743	6.9	5.968
28B	12°01′ N- 92°55′ E	27	0.3137	3.55	8.002
Northern Part:					
36A	13°00′ N-97°41′ E	37	0.2227	19.1	1.485
40	15°19′ N- 96°24′ E	10	0.2614	9.4	3.004
42	15°08′ N- 94°54′ E	16	0.2354	9.55	3.322
43	15°08′ N- 94°04′ E	30	0.3063	6.024	7.251
50A	19°27′ N- 92°32′ E	550	0.2440	8.05	2.156
48	19°41′ N- 93°08′ E	21	0.2630	5.15	4.895
47B	19°50′ N- 92°55′ E	17	0.2527	6.55	2.318

The geochemical behaviour of phosphorus has been studied by several oceanographers and marine biologists. In the present study, it has been noticed that there is regional variation in phosphorus content, an increase in the concentration of this element from north to south. There is also significant increase in the content of calcium towards south *i.e.*, lower latitudes (Table 1). Fig. 1b shows the covariance of calcium and phosphorus in the sediments of eastern part of Bay of Bengal. Higher amounts of phosphorus are found in the calcareous sediments of the southern part compared to the terrigenous sediments of the northern part. The increase in both calcium and phosphorus towards south and the covariance exhibited by these two constituents (Fig. 1b) indicate a geochemical affinity between them. Most probably, calcium and phosphorus are being coprecipitated in the form of calcium phosphate. Rao and Rao (1969) have reported that the southern part is characterised by high calcium carbonate content (45%). Sewell (1925) recorded the occurrence of extensive Globigerina ooze in the southern region which explains the high percentage of calcium carbonate in this region. The calcium content may stimulate the precipitation of phosphorus, as reported by Bhushinski (1964). Krauskopf (1967) on the basis of solubilities stated that the calcium phosphate would precipitate under the same general conditions as calcium carbonate.

Sengupta and Pylee (1966) have reported very high specific alkalinity of Andaman Sea waters. In view of the alkalinity of these waters, it may be concluded that the phosphorus present in the sediments of the eastern part of Bay of Bengal occurs as calcium phosphate precipitate. This conclusion is based on the observation that precipitation of calcium phosphate is favoured in alkaline waters with pH above 7.5 (Krumbein and Garrels, 1952; Landergren, 1954; Swanson, 1961).

The calcium phosphates of biological origion are generally the teeth of fish and carbones of whales which can contribute a few percent by weight to slowly accumulating pelagic deposits (Goldberg, 1963). It has been found by Zernova and Ivannov (1964) that Andaman Sea is a region of highest productivity of phytoplankton in the northern Indian Ocean. It is believed that the accumulation of phosphate is a direct response to organic activity, in that the organic matter from both pelagic and bottom-dwelling organisms piles up so rapidly that its phosphorus content is partly converted to apatite before it is entirely consumed by scavengers (Krauskopf, 1967).

Renn (1937) has pointed out regeneration of phosphate from the dead bacterial cells. Regeneration of phosphates by bacterial action has been fairly well established. It is also possible that the phosphorus cycle is being enacted in the upper lighted zone. Very rapid phosphate regeneration from the bacterial decomposition of diatoms was observed (Waksman *et al.*, 1937).

It has been reported by Rao and Rao (1968) that the percentage of organic matter in the sediments of the southern part is much higher than that of the northern part. In the light of the foregoing information, the differences in the concentration of total phosphorus in sediments of the two regions of the eastern part of Bay of Bengal may be attributed to the corresponding variations in the levels of biological productivity.

CONCLUSIONS

Geochemical study of fifteen clay-sized marine sediments from the eastern part of Bay of Bengal reveals that phosphorus is being fixed in these sediments as calcium phosphate. It has been found that the concentration of total phosphorus in bottom sediments increases from north to south, the latter area being characterised by high $CaCo_3$ content and organic matter. Finally, it may be concluded that the phosphorus in the marine sediments of the area under investigation is mostly biogenic in origin.

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DISCUSSION

R. VISWANATHAN: An increase in phosphorus content of sediments in the southern region has been attributed to high plankton productivity. Calcium and organic matter in sediments were also high; was this due to high percentage of calcareous organisms in the plankton?

M. RAMAMURTHY: Yes The high calcium carbonate in the sediments is due to the high percentage of calcareous organisms, particularly Globigerina.

A. K. GANGULY: On the question of marine biogenic phosphate, the following suggestions are made – 1. The dissolved (devoid of particulate matter) organic PO_4 is associated almost completely with deoxyribonucleic acid as observed in the coastal waters off Bombay, and 2. As regards the organic PO_4 in sediments, it is found to be associated with the humus material on the surface of the sedimentary particles.

A. K. DATTA: The increase in phosphorus content from north to south in Bay of Bengal may be due to and directly controlled by the greater turbidity near the mouth of the Ganges. In some cases phosphorites are found associated in fossil sediments where no marine animal fossils are so far known, *e.g.*, in krol sediments.

M. RAMAMURTHY: Regarding point 1, the phosphorus content in the sediments under consideration has not been studied in relation to the turbidity. As such, we cannot offer any comment on this point. Regarding point 2, the phosphorites referred to might have been formed due to inorganic precipitation.

D. LAL: I still do not see any compelling reasons to postulate the biogenic origin of phosphate.

M. RAMARUTHY: The covariance between contents of phosphorus and organic matter (mostly biogenic in origin) in the sediments under consideration and the presence of high percentage of calcareous organisms particularly Globigerina lead to the inference that a major part of the phosphorus is biogenic in origin. Another important point to be noted is that in the northern region, the phosphorus content is less even though there is a lot of contribution of terrigenous material. This rules out the possibility of inorganic phosphate being contributed by rivers.