

Ca⁺⁺/Mg⁺⁺ RATIOS IN THE SEDIMENTS ON THE CONTINENTAL SHELF OFF BOMBAY

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ABSTRACT

Low values of Ca/Mg ratio (4.7-14.0) have been obtained in the skeletal and non-skeletal (oolite) components of the carbonate fraction of the sediments on the continental shelf off Bombay, a terrigenous-carbonate province. Low ratio has been attributed to the greater quantity of magnesium present. The excess magnesium is assumed to be derived from various sources. The principal sources being dolomite and magnesium rich foraminifera and algae. Subsidiary amounts is expected to be contributed by incorporation from the magnesium-rich shelf waters which in turn may have derived the magnesium from dissolution from the sediment and in part by river discharge.

THE distribution of calcium and magnesium in the carbonate fraction of the sediments of the Fifty Fathom Flat, a submarine terrace on the outer continental shelf off Bombay has been presented in this note. The principal purpose of this study is to understand the environment of deposition of the carbonate sediments comprising oolitic sand, coral detritus and beach-rock which has been documented earlier (Nair, 1971).

In previous investigations of the western continental shelf (Schott, 1968; Nair, 1968, 1969), it has been shown that the sedimentary facies consists of a Recent nearshore terrigenous silty-clay facies grading seaward into a relict calcareous sand zone with carbonate content greater than 70%. Radiocarbon ages determined on two samples, one a composite sample from the outer shelf off Karwar and the other a coral fragment from off Bombay gave ages of 9135 ± 130 and 145 ± 95 years respectively. The composite sample due to contamination from Recent sediments probably indicates only the lower limit whereas the latter suggests the presence of living deep-water corals.

The sedimentary facies, in brief, is suggestive of a terrigenous-carbonate province intermediate between the Florida-Bahamas area and the Great Barrier Reef as compared by Maxwell and Swinchatt (1969).

FIELD AND LABORATORY METHODS

Samples were collected with a gravity corer, LaFond-Dietz snapper, and dredge. The top few centimeters of the core sample and a representative sample from the snapper sample were wet-sieved. The coarse fraction retained on the 63 micron sieve was further sieved at 0.5 ϕ interval.

The skeletal fraction (molluscs, bryozoa, coral and others) was then separated by hand-picking the shell fragments from the + 35 mesh sieve. The non-skeletal fraction consisting of oolites were concentrated by a combination of rolling on an inclined sheet of paper and hand-picking under a binocular microscope. The separated fractions were analysed by the EDTA method for Ca and Ca + Mg using the indicators murexide and eriochrome black-T respectively. The precision of the Ca/Mg ratio thus determined is ± 2 per cent. Differences in the value greater than 2 per cent is considered quantitative. Insoluble residue of the coarse fraction was obtained by treating the sample with 10 per cent HCl. Results are summarised in Table I.

RESULTS

The Ca/Mg ratio in the samples are very much lower and have a narrow range as compared to Recent carbonate sediments investigated by Taft and Harbough (1964) who reported Ca/Mg ratio of 6-151, 16.8-93.0, and 22.1-212.3 from Southern Florida, Bahama Islands, and Andros Islands respectively. Magnesium content of the outer portion of the oolites have been reported by Kinsman (1969) for the Bahamas (650 ppm), Persian Gulf (1,333 ppm) and Pilkey, Blackwelder Doyle, Estes, Terlecky (1969) for the continental shelf of southern USA (6,335 ppm). These values which are for the surface portion of the oolites are however not strictly comparable to the value of 37,000 parts per million of magnesium for the whole sample obtained in the present study. Most of the oolites on the western continental shelf are superficial oolites and therefore the bulk of the magnesium is expected to be contributed by the nucleus and lesser amounts from the superficial coating around the nucleus.

The magnesium content of the beachrock sample (cement + grains) is 36,000 ppm, which is comparable to the value obtained by Gavish and

TABLE I
Skeletal fractions

Sample No.	Depth in meters	Ca‰	Mg‰	Ca/Mg	% > 63 μ	% Insoluble residue in coarse fraction
40	62	296	36	8.2	67.1	22.1
41	87	304	36	8.5	83.5	5.9
42	96	280	36	7.7	Beachrock	0.9
43	204	272	70	3.8	4.3	74.3
49	81	276	46	6.0	86.0	7.8
50	86	297	41	7.2	92.4	2.7
A	49	220	46	4.7	4.5	13.8
B	77	252	49	5.2	38.4	13.9
C	82	280	48	5.8	41.0	8.0
D	85	296	23	14.0	38.0	11.2
E	86	272	53	5.1	59.0	6.3
F	86	276	53	5.2	59.2	6.7
<i>Oolites</i>						
41	87	288	36	8.0	..	..
42	96	284	44	6.4	..	..
49	81	280	29	9.6	..	..
50	86	313	53	5.8	..	..
B	77	228	53	4.2	..	..
C	82	276	27	6.4	..	..
D	85	248	39	6.4	..	..

Friedman (1969) for Recent beachrocks on the Mediterranean coast of Israel. The Ca/Mg ratio is, however, approximately half that of the Recent beachrocks reported by Taft and Harbaugh (1964) from the Bahamas.

Calcium and magnesium content for samples from the continental shelf south of Bombay have been reported by Gogate, Sastry, Krishna-

murthy, Viswanathan, Table III, p. 173 (1970). Ca/Mg ratio in their samples range from 0.9 to 375 and are not only not comparable to the values obtained in the present study but also become difficult to explain particularly when dealing with the bulk sediment which is a multi-component system consisting of an admixture of organic and inorganic constituents of differing chemical composition.

DISCUSSION

Calcium and magnesium content in the shells of marine and freshwater invertebrates are governed mainly by the following factors: (1) water chemistry, (2) skeletal mineralogy (aragonite, low-Mg calcite, high-Mg calcite and calcite), (3) physiology of the organism, (4) physico-chemical environmental factors (temperature and salinity). Subsequent to the death and deposition of the organism, various chemical and physical processes tend to modify the original composition of the shell and associated sediments. Such alterations in the chemical and physical properties particularly at low temperatures and pressures is termed diagenesis (Chillingar, Bissel and Wolf, 1967). One effect of diagenesis that has been extensively studied is the variation in elemental composition with time. Experimental data (Schroeder, 1969 and references cited therein) and field investigations (Stehli and Hower, 1961; Gavish and Friedman, 1969 and others) have shown that there is a progressive decrease in the magnesium content (as well as calcium and strontium) with age in the sediments.

The results of the analysis in the present study indicate a consistently low Ca/Mg ratio. Low Ca/Mg ratios would mean that magnesium is present in greater abundance in respect to the calcium present. In seeking an explanation for the excess magnesium present, Taft and Harbaugh (1964) were of the opinion that sources such as aragonite, low-magnesium calcite form only trace quantities. Contribution of magnesium absorbed on clays can be ruled out in the present study as the analyses were done exclusively on the coarse fraction. Dolomite even in small quantities will however be sufficient to account for the excess magnesium. Dolomite has been reported to occur between 5-10% in the shelf sediments off Bombay (Stewart, Pilkey and Nelson, 1965) and it is therefore possible that the high magnesium content is in part contributed by dolomite. A consistently high magnesium content in the oolites also indicates that enrichment has taken place in purely inorganic precipitates. As mentioned earlier the distribution of magnesium in the sediments is in part controlled by the chemistry of the

waters, particularly its availability. In this context, the findings of Viswanathan, Shah and Unni (1968) that the Mg/Cl ratio (0.07157) in the shelf waters is higher than average suggests the presence in the waters of readily available source of magnesium which may facilitate the process of enrichment. An explanation for the high magnesium in the waters has however to be sought. Two possible mechanisms of magnesium contribution are possible. River discharge, particularly the Narmada which flows through extensive 'limestone' terrain (Krishnan, 1962) and debouches into the Gulf of Cambay, can contribute to the shelf waters. Alternately the dissolution of magnesium from the sediment itself (Schroeder, 1969) can add to the magnesium content to the waters. Magnesium thus released becomes available for reprecipitation.

Additional possible sources of magnesium in marine sediments are coralline algae and foraminifera which are considered to be made up of high magnesium calcite (Chave, 1962; Taft and Harbaugh, 1964; Milliman, Ross and Teh-Lung Ku, 1969). These factors probably account for the lowest Ca/Mg ratio (3.8) obtained in sample (No. 43) from the continental slope, the coarse fraction of which was essentially pure foraminifera with lesser amounts of algal filaments, the latter also contributing to the magnesium content of the beachrock in which through the examination of the thin section and insoluble residue their presence was observed.

Chillingar (1960) found that the Ca/Mg ratio of the carbonate sediments increases with distance from shore which he attributed to the abundance of magnesium-rich coralline algae in the nearshore waters. The samples under study do not show any such clear cut trend. It is, however, possible to delineate two broad areas, one with a ratio of 7 (samples 40 through 50, excluding 43) and the other with a ratio of 5 (Nos. A through F). The explanation offered at present to account for this distribution, namely that the effect of river discharge (by providing greater amount of magnesium) is greater for the locations with the lower Ca/Mg ratio, may be considered as tentative. If the amount of insoluble residue is taken as a measure of the influx of terrigenous contribution by way of rivers, then the samples A through F including No. 40 having a higher content of insoluble residue would seem to indicate the essential validity of the assumption. An alternate method of arriving at the same conclusion would be to evaluate whether the variation in the ratio has any relation with distance, not from the western coast but from the Gulf of Cambay into which the major rivers (Narmada, Tapti) discharge their load and which in turn is expected to influence the sediment

distribution on the adjacent shelf. That this in fact is the case is evident from Fig. 1.

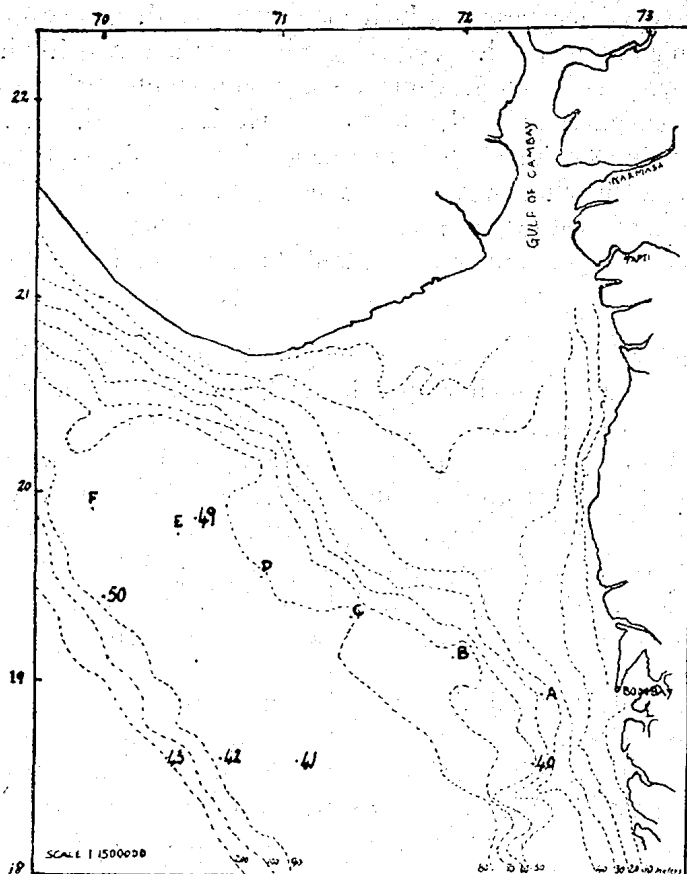


FIG. 1. Map showing sample locations. Bathymetry from Admiralty Charts.

In conclusion it may be stated that a number of sources have been invoked to explain the presence of excess magnesium in the sediments under study. Available data do not permit the discrimination in detail of the various sources but may become possible with the availability of the carbonate mineralogy of skeletal and non-skeletal fractions.

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