

Pre- and post-monsoonal changes in grain size and heavy minerals in the sediments from Kalbadevi Bay, Ratnagiri, west coast of India

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Sediments from the Kalbadevi Bay, Ratnagiri collected during January, May and October have been studied for processes responsible for the observed grain size variations and heavy mineral distribution. The study shows transportation of loose sand fractions from shallow depth (< 5 m) during the SW monsoon and deposition in deeper depths (>10 m) during post-monsoon. It is further inferred that the E-W trending depression in the central part of the Bay partially controls the sand distribution. Clay accumulation in the Bay begins after the culmination of monsoonal effects. Distribution of ilmenite appears similar to that of magnetite. Pre- and post- monsoonal changes in the distribution pattern of heavy minerals show that fine to very fine particles (< 62.5 μ) of magnetite and ilmenite have maximum concentration (14 to 26 % and 14 to 29 % respectively) in the month of October (post-monsoon). This may be due influence of strong currents in the Bay after the culmination of SW monsoon.

[Keywords: Heavy minerals, grain size, offshore, environment, placers]

Introduction

Occurrence heavy mineral placers in the form of black sand (ilmenite and magnetite) along the beaches and offshore Konkan coast, Maharashtra are well known¹⁻¹². Based upon mineral assemblages (ilmenite, magnetite, hornblende, diopside, augite, zircon and kynite), earlier workers¹⁻⁴ suggested Deccan Traps as the major source for these placers, whereas others ascribed it to hinterland laterites⁵, mixed sources⁶, mixed provenance⁷, and metamorphic rocks¹² as the source.

Kalbadevi Bay of Ratnagiri is ~ 5 km long, 250 m wide, and two streams⁴ join the Bay in the northern and southern end. Although the nature, distribution and economic evaluation of these deposits have been elucidated, the role of oceanographic processes involved in their formation is not much understood. Considering the future onshore and offshore placer mining possibility in Kalbadevi Bay, the National Institute of Oceanography (NIO), Goa, carried out onshore environmental studies¹³ in phases from 2004, and offshore area in 2006 for three seasons during January, May and October (transitional, pre-monsoon and post-monsoon respectively¹⁴). Initial results on the heavy mineral variations⁶ of Kalbadevi Bay were expressed on the sediment fraction weight rather than total weight of the sample. In the present study the

results are presented on the basis of total sample weights and used the mean grain size data for discussion to understand more precisely the oceanic processes involved in the Bay by comparing the pre-and post-monsoonal offshore data.

Materials and Methods

The offshore surface sediment samples (24 no.) in the Kalbadevi Bay were collected along three profiles (OP-01 in north, OP-02 in center and OP-03 in south, and a reference point (OP-S O/1; Fig. 1), at 5, 8 and 10 m water depth using hand operated Van-Veen grab in 2006. The offshore profiles were the extension of onshore beach profiles¹⁴. The samples along OP-01 profile were collected only during January, 2006. The coordinates of sampling locations were obtained by Garmin GPS hand set (model no. 76 csx) with accuracy of 5-7 m. The samples were washed repeatedly with distilled water to remove salt content. The carbonates, organic matter and ferruginous coatings of samples were removed by treating with 1:10 HCl, H₂O₂ (30% by vol.) and SnCl₂ respectively and the treated samples were dried in an oven at 40°C. Representative samples (dried) were weighed after coning and quartering and different size fractions were collected on sieves of 0.5 phi (Φ) interval by dry sieving. The sand, silt and clay percentages were

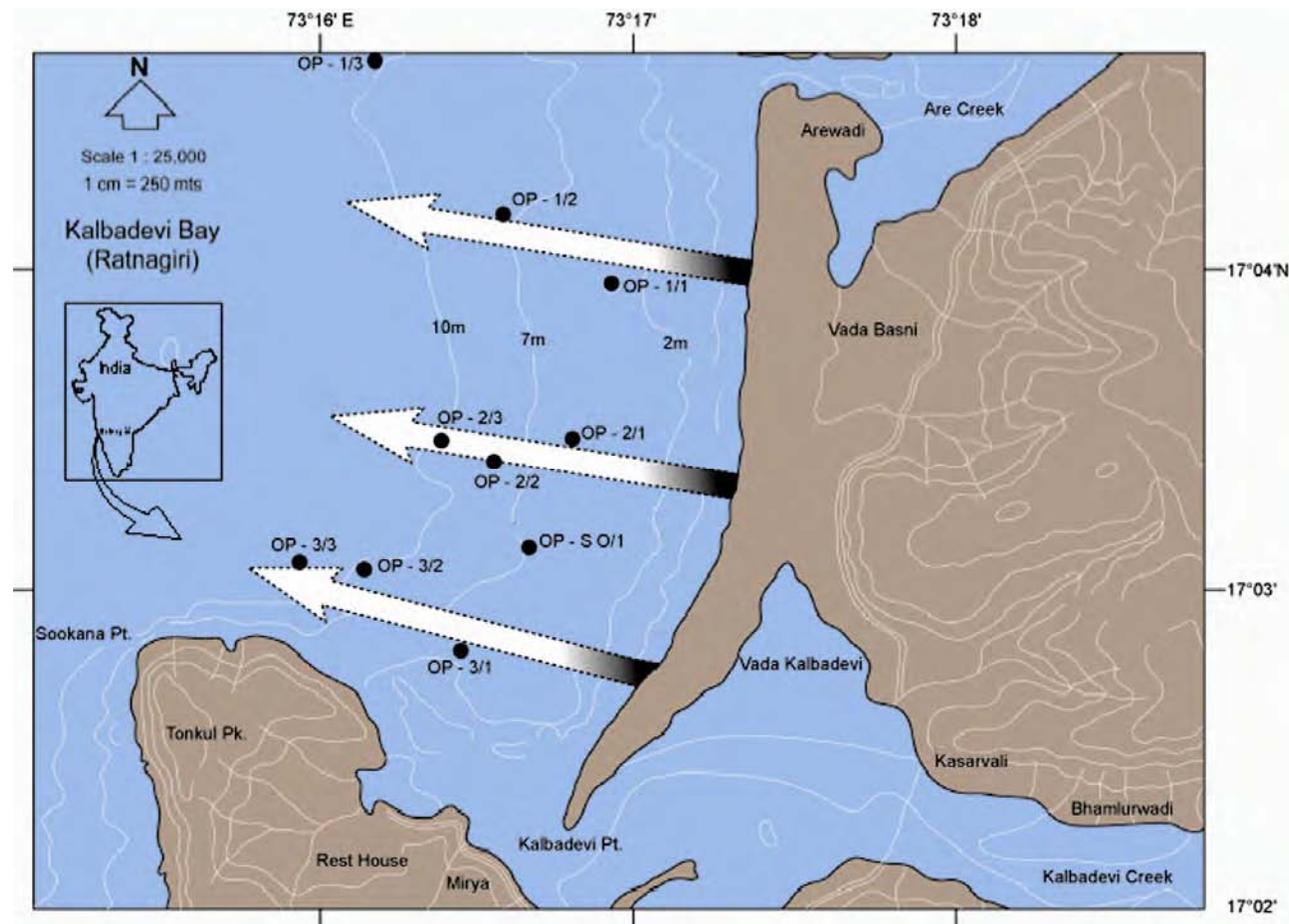


Fig. 1—Sampling stations along OP-1, OP-2 and OP-3 profile in Kalbadevi Bay, Ratnagiri, during January, May and October, 2006.

determined by the standard pipette analysis¹⁵ and heavy mineral content was determined by using bromoform of 2.89 sp. gr. following standard procedures¹⁶. The comparative study includes the samples from OP-02 and OP-03 profiles collected during January (transition), May (pre-monsoon) and October (post-monsoon) 2006, and not from those along OP-01 in January as no samples were obtained during May and October, 2006.

Results

Major composition of the sediments along both offshore profiles is sand which varied from 95 to 98% during January, 95 to 99% in May and 98 to 99% during October (Fig. 2a). Similarly, the silt content along these profiles varied from 0.5 to 3% during January, 0.01 to 3% in May and 0.04 to 0.9% in October (Fig. 2b), and the clay content varied from 0.8 to 2.5% during January, 0.2 to 1.7% in May and 0 to 0.01% in October (Fig. 2c). Sand content at reference point (SO/1) reduced from 99 to 96%

during May and increased to 99% in October. Comparison of data of pre- and post-monsoon and transitional period showed not much variation in the sand, silt and clay content and the changes are up to 2.7, 2.9 and 0.15% respectively. Sediments at the reference point showed small variation in sand with 2.8% decrease during May and 3.4% increase during October.

The mean grain size showed much variation along OP-02 and OP-03 profile during three months, but at the reference point the change is minimum (0.08 to 0.09 mm; Fig. 5). Comparatively, the variation along OP-03 profile is larger (0.09 to 0.16 mm) than along OP-02 (0.07 to 0.12 mm). During May, both the profiles showed minimum range of mean grain size (0.07, and 0.09 to 0.1 mm for OP-02 and OP-03 respectively), but in October, the range enlarged (0.08 to 0.12, and 0.09 to 0.16 mm for OP-02 and OP-03 respectively).

Magnetite distribution along OP-02 and OP-03 profiles and at reference point showed variation with

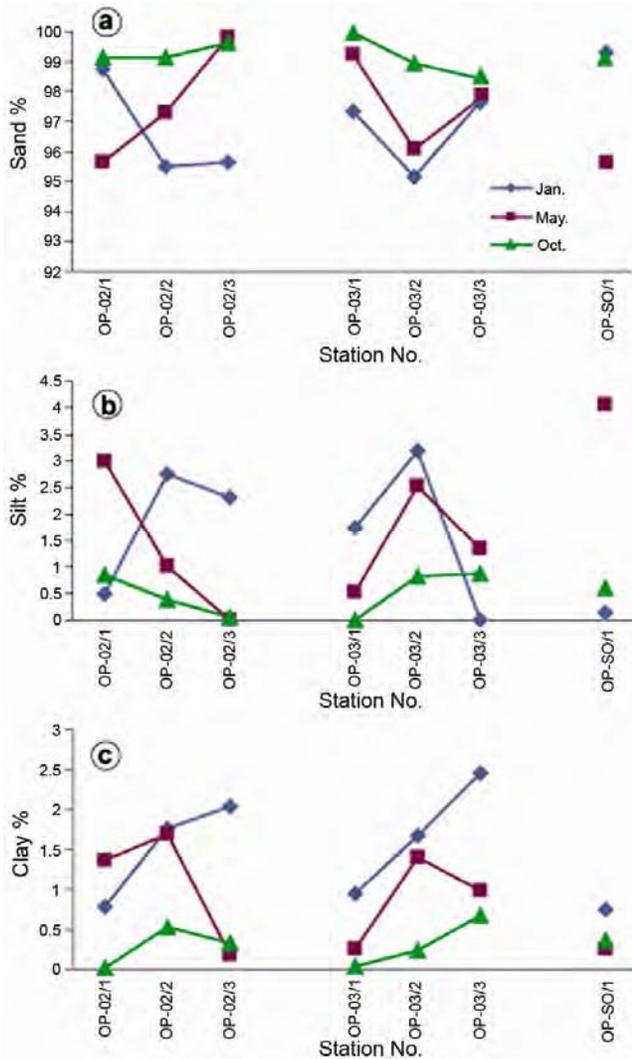


Fig. 2—Variation in (a) sand, (b) silt and (c) clay along OP-02 and OP-03 profiles during January (Jan.), May and October (Oct.), 2006.

respect to depth, month and season (Figs 3a to 3g). The magnetite along OP-02 comparatively have smaller range (up to 13%) than that along OP-03 (up to 26%). Highest magnetite content in both the profiles varied with respect to depth and month. The magnetite content along OP-02 profile (Figs 3a-c) increased from ~3% in January (5 m) to 7% in May (8 m) and 14% (8 m) during October, whereas along OP-03 profile (Figs 3d-f), it remained unchanged during January (1.5% change, 10 m) and May (1.4% change, 10 m), and increased to 26% during October (8 m, Fig. 3g).

Highest content of magnetite appears confined to 125 and < 62.5 μ fractions especially during May and October. Finer size particles of magnetite show an

increase in all three months. During October, the magnetite content in 5 m depth is comparatively lower than that at 8 and 10 m depths (Figs 3a and 3d). During January and May, where the finer magnetite particles show an increase with decrease of size, the magnetite behave opposite of October and show a decrease in concentration with decrease of size. At the reference point (OP-S O/1, Fig. 3g), although the magnetite concentration increased with decrease in particle size, the maximum content of magnetite in the fine fractions remained nearly constant (2 to 2.4%) with respect to three months.

The ilmenite distribution along OP-02 and OP-03 profiles and at a reference point (Figs 4a to 3g) show that the smaller particles of ilmenite have higher content during January and May, but very fine particles of ilmenite show a decrease in October. Ilmenite content in sediments from 5, 8 and 10 m depth along OP-02 and OP-03 have much variations during January, May and October, and that the range along OP-02 is larger (up to 29%) than along OP-03 (up to 17%) profile (Figs. 4a to 4f). Highest percentage of ilmenite in the samples from different depth during three seasons remained nearly constant (i.e. 25% at 5 m, 27% at 8 m, and 29% at 10 m depth) along OP-02, whereas, there was large variations (16% at 5 m, 13% at 8 m and 17% at 10 m depths) along OP-03. The maximum content of ilmenite in the sediments at the reference point (OP-S O/1) during all three months was different and the graph shows an increase in the content towards finer fractions during January, May and October (Fig. 4g).

Discussion

The sand and silt have opposite trends along OP-02 and OP-03 profile (Figs 2a and 2b). Sand profiles along OP-02 and OP-03 show different trends with respect to three months (corresponding three seasons) and thereby suggest influence of other parameters (Fig. 2a). Sand content along OP-02 profile decreased with depth in January but increased in May and October. Therefore, the increase of sand content can be related to the monsoonal effects, where higher sand is derived from the shallow depths due to the wave action. It appears that the sand deposited during the monsoon period does not get compacted and therefore removed during transition period, thereby resulting in the reduction of sand percentage in January. The removal of sand is probably more effective due to the influence of E-W trending depression present in the central part of

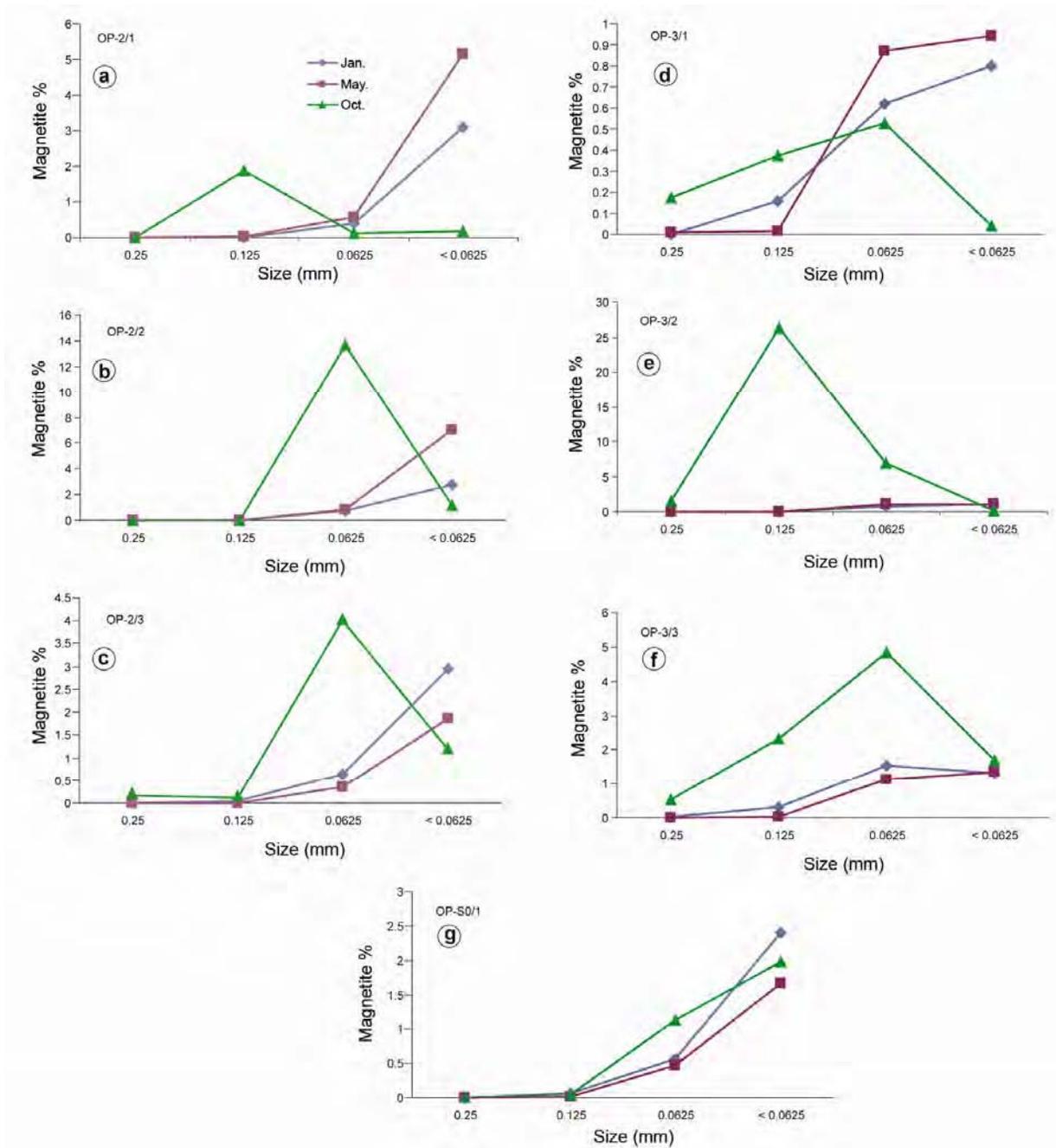


Fig. 3—Variation in magnetite content along OP-02 (a, b & c), OP-03 (d, e & f) profiles and at reference station (g) during January (Jan.), May and October (Oct.), 2006.

the Bay⁶ which apparently coincided with the trend of OP-02 profile. In addition, the convergent and divergent littoral currents in the Bay⁶ might be significantly contributing the movement of sand to deeper levels. It has been indicated¹⁷ that the predominant wave direction in the Bay varies from SW, WSW, W, and WNW with wave period between 5 to 14 seconds, which supports the above possibility.

In contrast, the trends along OP-03 show much variation (Figs 2 a-c), and that the sand content increase with depth during three months suggesting input from the shallow depth. The pre-monsoonal effects are clearly indicated due to increase of sand at 10 m depth during May (99.8%), which remained constant up to October (99.6%) along OP-02 and OP-03 (97.7% in May and 98.5% in October). This

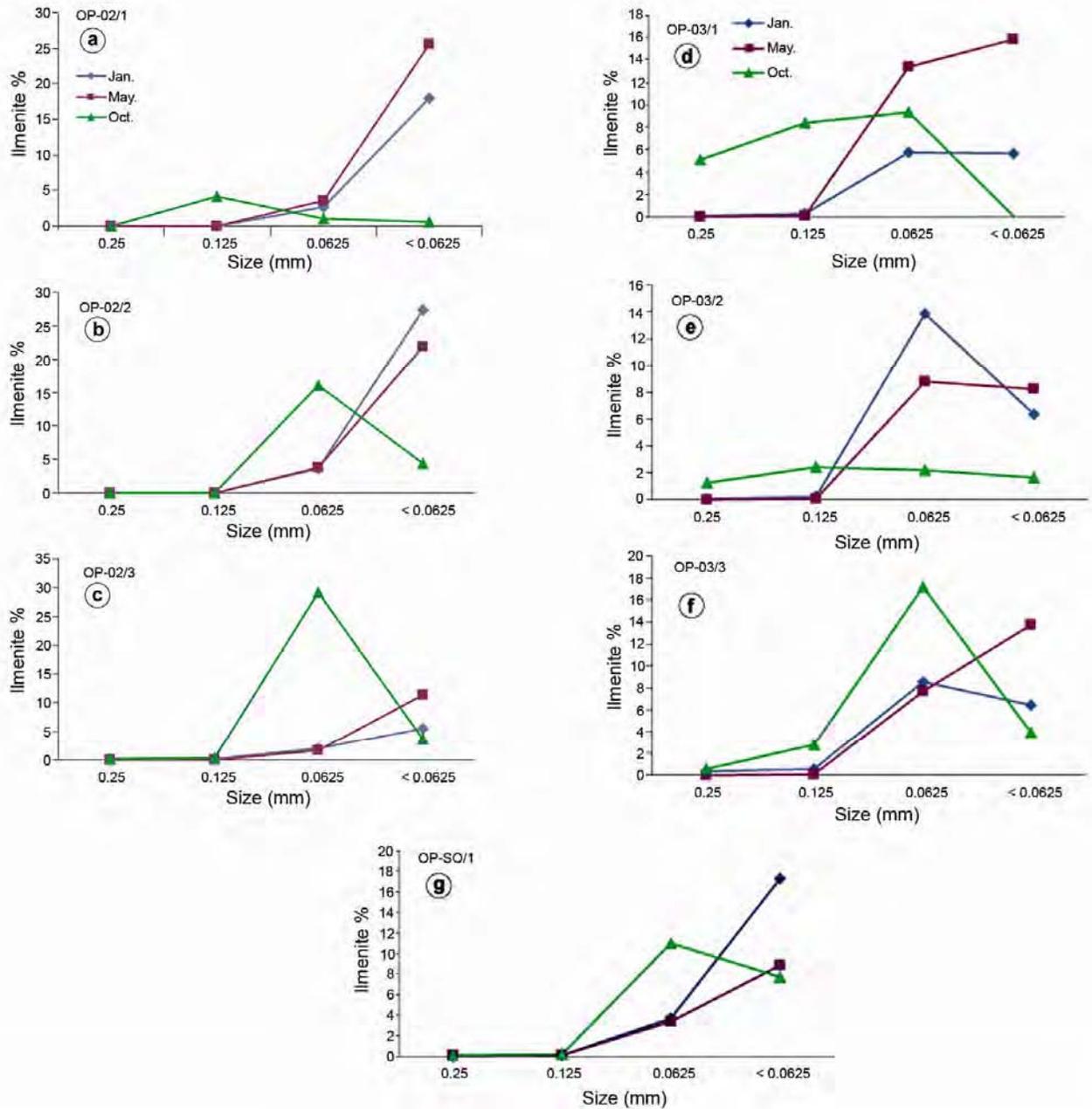


Fig. 4—Variation in ilmenite content along OP-02 (a, b & c), OP-03 (d, e & f) profile, and at reference station (g) during January (Jan.), May and October (Oct.), 2006.

observation further suggests that the strong monsoonal winds are quite effective and along with the currents causes reasonable sediment discharge leading to turbulence in the Bay. It is also possible that the southern stream transport the sand to much deeper (10 m) depth. The overall increase in sand during May and October as compared to January indicates movement of sand towards offshore area. The distribution of

sand along the central (OP-02) and southern profile (OP-03) therefore appears even and unidirectional (westward). Similarly, the clay trends along OP-02 and OP-03 profile are comparable during three months (Fig. 2c). Although the total clay content in the sediments is quite low, it reduces further from ~ 2.5% in January to < 0.5% in October, suggesting that the clay accumulation the Bay initiate after the monsoon period (June to September).

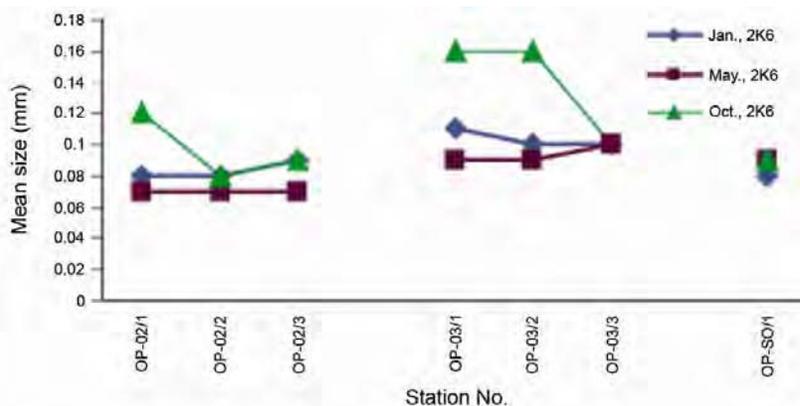


Fig. 5—Variation in mean grain size along OP-02 and OP-03 profile, and at reference station during January (Jan.), May and October (Oct.), 2006.

Comparatively, the finer fractions of the sediments ($< 125 \mu$) are important as they have the maximum heavy mineral content during pre-and post- monsoon and transitional period. The magnetite trends along OP-02 and OP-03 profile are similar and show no effect of the channel existing in the middle of the Bay (Figs 3 a-g). The magnetite percentage typically increase after the monsoon and reach to maximum (14% for OP-02/2 and 26% OP-03/2) during October (Figs 3b and 3e respectively). It is further observed that, the magnetite concentration increase towards fine fractions in January and May, whereas the concentrations decrease towards very fine fractions (62.5μ) in October, suggesting that the fine particles of magnetite are removed from the Bay after the monsoon due to current action and deposited to the deeper part of the shelf.

The offshore non-magnetite heavy minerals in Kalbadevi Bay are predominantly ilmenite. The distribution of ilmenite appears similar to that of magnetite, where the fine fractions of ilmenite have the highest concentrations during pre-and post-monsoon and transition period. It is noted that, OP-02 profile has comparatively higher range of ilmenite (25 to 29%) than OP-03 (14 to 17%) during January, May and October. The similar trends of ilmenite and magnetite along OP-02 and OP-03 profile and at the reference point (Figs 4a to 4g) indicate that the heavy mineral distribution in the Bay is controlled by the same oceanic process. It appears that the very fine ilmenite particles in the Bay are channelized along the E-W depression⁶ and moved away from the area. Therefore, presence of E-W depression

in the Bay along the middle profile is responsible for higher content of ilmenite.

It is observed that, the mean grain size of the sediments from 5 to 10 m depth along OP-02 and OP-03 profile is reduced prior to the monsoon (January to May). The monsoonal effects (June to September) on the sediments are quite visible due to increase in the mean grain size, which is also reflected in the increase of the sand content. However, comparatively higher mean grain size of the sediments during October (Fig. 5) indicates transportation of sand to the offshore region. Systematic decrease in the mean grain size after the monsoon indicates deposition of clay particles in the Bay most probably by the action of current patterns in the area thereby increasing clay content in January.

Conclusions

The Kalbadevi Bay sediments show changes in sand and clay content in response to pre- and post-monsoon, and suggest that clay accumulation in the Bay initiates during post-monsoon period. Heavy minerals in the Bay are concentrated in the finer fractions ($< 62.5 \mu$) of the sediments, and the ilmenite and magnetite distribution patterns remain similar during pre- and post-monsoon period. Fine particles ($< 62.5 \mu$) of heavy minerals appear to be transported from the Bay to deeper part of the shelf after the monsoon due to strong current action with some control of the E-W depression in the center.

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