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Environmental and Provinance study of Mudflats from Shastri Estuary, Ratnagiri District, Maharashtra using Clay Minerals

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ABSTRACT

Coastal environment is most active, dynamic and transitional in nature and is characterized by the interplay of continental and marine environments. Estuary represents a most complex environment, developed in the transitional ecotone environment at the confluence point of river and sea. The Konkan Coastal Belt (KCB) of Maharashtra is traversed by eighteen major and thirty-six minor west flowing perennial rivers, originate in the Western Ghats and produce remarkable mud flats along their course. Shastri is one of the most important estuaries of west coast of Maharashtra. During present investigations, sedimentological, clay mineralogical studies of mud-flats from Shastri estuary have been carried with respect to genesis, environmental and provenance using pipette analysis, X-ray diffraction and I-R studies. Representative mud samples have been analyzed. In all samples, the water-soluble salts are found to be negligible in quantity than acid soluble salts. All sediment samples contain significant number of fines with < 63 ìm size. Pipette analysis shows that the sediments from mouth of estuary are of silty- sand type whereas the sediments from middle and upper reach of sandy-silt in nature. X-ray diffraction and I R studies show the presence of kaolinite, goethite, gibbsite, illite, muscovite, chlorite and montmorillonite minerals. The presence of particular clay mineral is due to chemical weathering of the host rock in humid and subtropical conditions. The process of laterization of basalt involves leaching of the most of the oxides from pyroxenes and feldspars. This leaching process is responsible for the formation of different clay minerals in the residual deposit.

Key words: *Environment, Shastri, Clay, X-ray diffraction, Basalt*

Introduction

The West Coast of India (WCI) has attracted the attention of many geo-scientist due to its neo-tectonic set up, continuing seismic activities, sea level changes, marine and estuarine environment as well as due to environmental degradation. The estuarine processes are more complex in tropical environment . According to Karbassi *et al.* (2008), the sediment volume fluctuates with in river-dominated estuaries. The intertidal mudflats are prominent sub-environments found on the fringe of estuaries (O' Brine, *et al.,* 2000). According to Reinecke and Singh, (1980), the mudflats are developed where the wave action is not strong to disturb the fine sediments. Fine sediments of the mud flats are derived from terrestrial as well as marine regions and considerably modified in terms of mineralogy, texture and

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chemistry during the journey. (Shi and Chen, 1996). Numbers of Geo-scientists have contributed in relation with the sedimentological studies of the beach sand, Tertiary sediments and shales from different coastal zones of west coast of India. Review of literature shows that there is a scope to carry the sedimentological and mineralogical studies of the estuarine mud-samples in relation to environment of deposition. The Shastri represents one of the major rivers of west coast of Maharashtra. The present work has been attempted to carry out the detailed investigations related to sedimentological and clay mineralogical studies of the estuarine mud-samples of Shastri river Basin (SRB).

Materials and Methods

Study Area

SRB lies along the Western Coastal tract of India in Maharashtra state (lat.16^{0}57′N.; long.73^{0}15′E. and lat. 17^{0}30′N.; long. 73^0 50′ E.) (Fig.1, Fig. 2- Google Image). Shastri is a seventh ordere river having a length of about 72 km., flows in east-west direction It covers an area of about 2098 km^2 (SOI topographic sheet Nos. 47 G/3, G/4, G/7, G/8, G/11, G/12 and 47 H/9). The area falls in a tropical to subtropical humid climate with high rainfall, temperature and humidity. It receives average rainfall of 3000 mm.

Geology

SRB lies along the western periphery of the Deccan Trap province i.e. tholeiitic province of India, represented by basalts of Cretaceous to Eocene age. Deccan basalt lava flows belong to Ambenali and Poladpur formations of Wai sub-group (Mitchell and Cox, 1988), mainly exposed along river valleys, valley sides and near shore. These flows are capped by laterites of Pleistocene age while, the Quaternary sediments are exposed along the banks of Shastri River and its tributaries.

Fig. 1. Location Map of the Area (Shastri River Basin)

Drainage

Shastri river is characterized by presence of dendritic to sub-dendritic drainage pattern, with trellis and sub parallel at some places. It shows abnormal drainage characters at some places during the course indicating tectonic imprints viz. sharp bends, straight channels and ponding etc. at many places.

Sampling

The inter-tidal mud-flats are prominent in the lower and middle reaches, while poorly developed in the upper reaches of the Shastri estuary. The representative core samples of mud flats up to 10 cm depth were collected from six different localities, covering lower, middle and upper reaches of the estuary to carry the textural, mineralogical studies (Fig. 3). Two core samples of mud were collected near the mouth representing lower reach of the estuary (Tavsal 17^0 18^1 N, 73^0 14^1 E and Saitvada 17^0 15^1N, 73^0 15^1 E). Another two samples were collected from the middle part of the estuary (Agarnaral 17^0 12^1 N, 73^0 28^1 E and Phungus 17^0 12^1 N, 73^0 28^1 E)) and remaining two core samples were collected from the upper reaches of river (Sangmeshwar 17^0 11^1 N, 73^0 32^1 E and Phansavane 17 ^{0} 08′ N & 73 ^{0} 40′ E).

Insoluble Residue Analysis

Insoluble residue analysis of representative six samples (20 g) have been carried by following standard methods. The insoluble residue content was computed and results so obtained have been presented in Table 1.

Pipette Analysis

Insoluble residue analysis suggests that significant number of fines having < 63 ìm size are present in sediments. Pipette analysis of these sediments has been carried out (Krumbein and Petti John, 1938; Folk 1974; and Carver, 1971) and weights of various size fractions are calculated. The data so obtained has been presented (Table 2 and Fig. 4a, b and c).

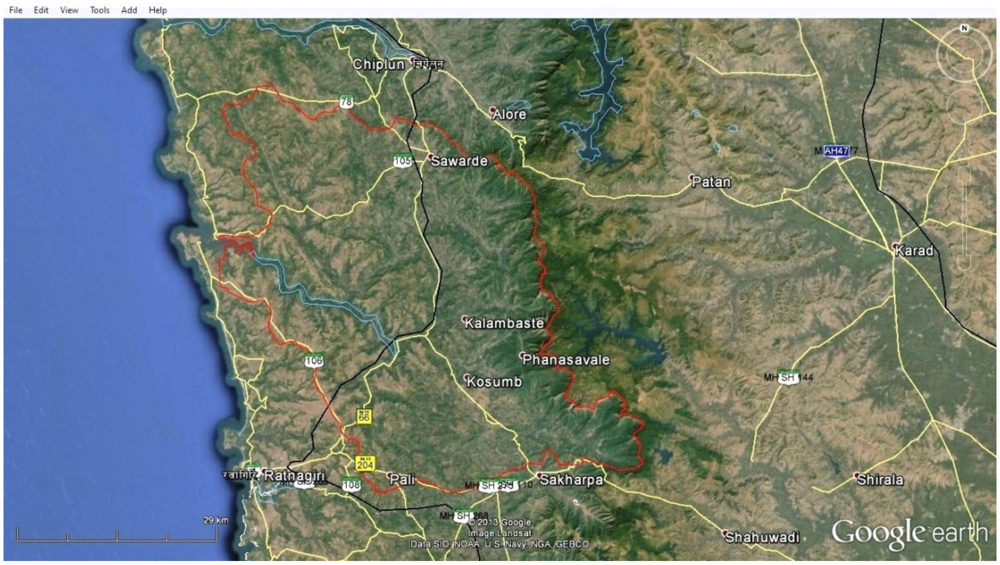

Fig. 2. Map of the SRB (Google Image)

Table 1. Insoluble Residue Content of the Mud Flat Samples from Shastri Estuary

Location	Sample No.	Position of Sample	Insoluble Residue %
Mouth	S1	Top	90.66
Tavsal		Bottom	88.89
Saitvada	S2	Top	91.45
		Bottom	91.88
Middle reach	S3	Top	86.80
Agarnaral		Bottom	89.89
Phungus	S4	Top	91.06
		Bottom	89.37
Upper reach	S5	Top	84.11
Sangmeshwar		Bottom	86.10
Phansavane	S6	Top	87.07
		Bottom	85.06

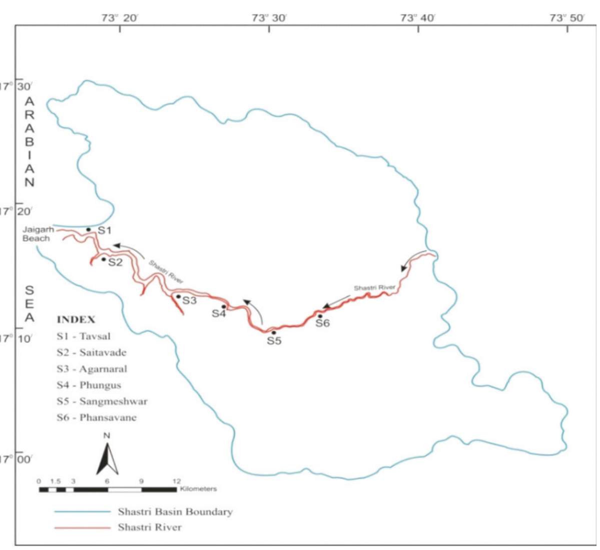

Fig. 3. Sample Location Map (SRB)

The percent size fractions present in each sample worked out as sand, silt and clay. The sand-silt-clay values obtained during pipette analysis have been plotted on the triangular diagram (Folk, 1980) (Fig. 5).

Clay Mineral Studies

Mud flats containing varieties of clay minerals are exposed at the mouth and along the Shastri estuary. The composition of clay depends mainly on the chemical composition of the parent minerals and physico-chemical environment under which the alteration takes place. The source and environment of deposition are important controlling factors of the clay mineralogy and their distribution (Grim, 1958). To understand these aspects, clay mineral studies of Shastri estuary is carried by following X-ray and Infra-Red Spectroscopic techniques.

X-Ray Diffraction Studies

The clay fractions of all six samples were examined and identified by using X-ray diffraction technique. The study has been carried out on a Phillip – 1710 X-ray diffractometer. The diffractograms were scanned within a range from 5^0 to 60^0 with a step width 0.02 and at speed of 2^0 per minute. The X-ray diffractograms for all mud samples are interpreted

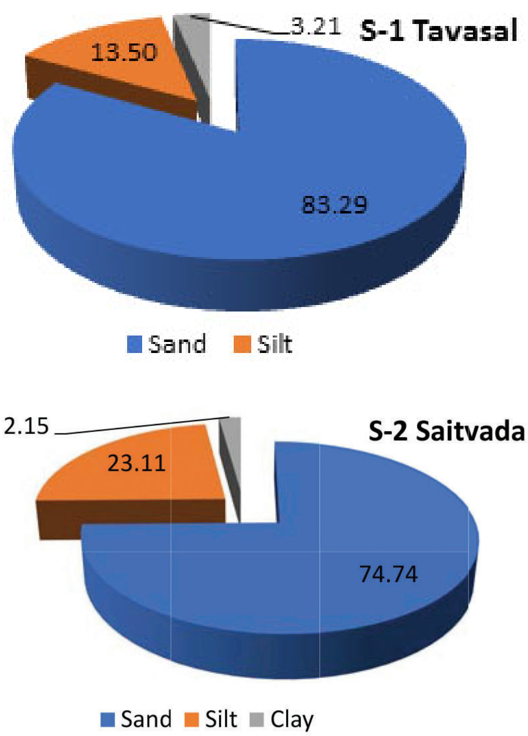

Fig. 4a. Grain Size Fractions (Sand – Silt – Clay) in Mudflat from Shastri Estuary (Lower Reach)

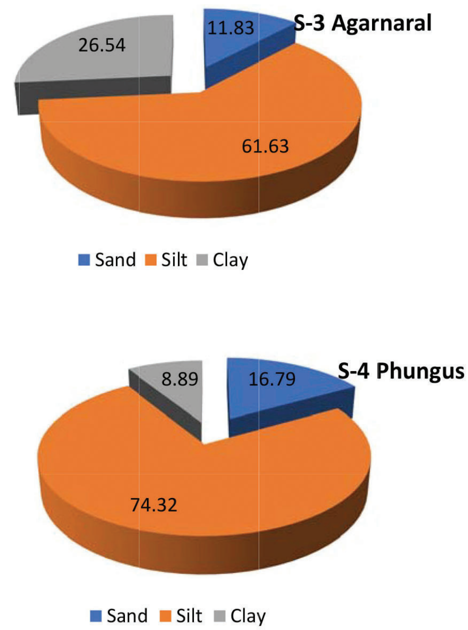

Fig. 4b. Grain Size Fractions (Sand – Silt – Clay) in Mudflat from Shastri Estuary (Middle Reach)

Table 2. Weight Percent of Sand, Slit and Clay of Mud Samples from Shastri Estuary

Sample No.	Sand	Slit	Clay
Mouth			
S–1 – Tavsal	83.29	13.50	3.21
S–2 – Saitavada	74.74	23.11	2.15
Middle Reach			
S–3 – Agarnaral	11.83	61.63	26.54
S–4 – Phungus	16.79	74.32	8.89
Upper Reach			
S–5 – Sangmeshwar	23.11	58.99	17.10
S–6 – Phansavane	21.77	60.52	17.71

Table 3. Semi-Quantitative abundances of clay minerals from X-Ray studies for mudflat samples of Shastri Estuary

Sample No.	Kaolinite	Goethite	Chlorite	Illite	Muscovite	Gibbsite	Montmorillonite
S-1	71.62	3.13	25.25	-	-	-	-
S-2	22.47	2.02	19.63	31.41	24.47	-	-
S-3	15.66	3.18	-	59.71	-	17.54	3.91
S-4	50.29	1.79	6.81	9.11	29.36	2.64	-
S-5	10.23	1.73	23.16	18.22	22.22	3.77	20.67
S-6	9.99	-	23.24	18.25	22.20	5.72	20.60
Mean	30.04	1.98	19.62	27.34	24.56	7.42	15.06

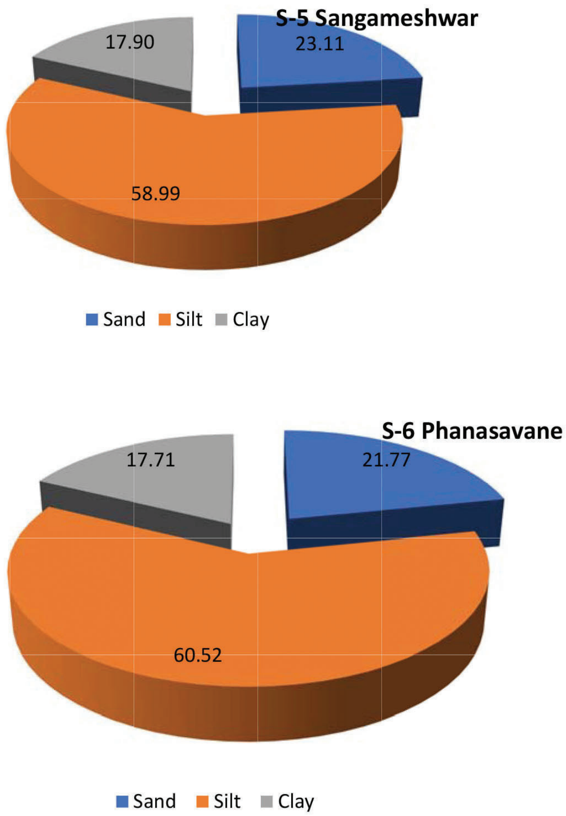

Fig. 4c. Grain Size Fractions (Sand – Silt – Clay) in Mudflat from Shastri Estuary (Upper Reach)

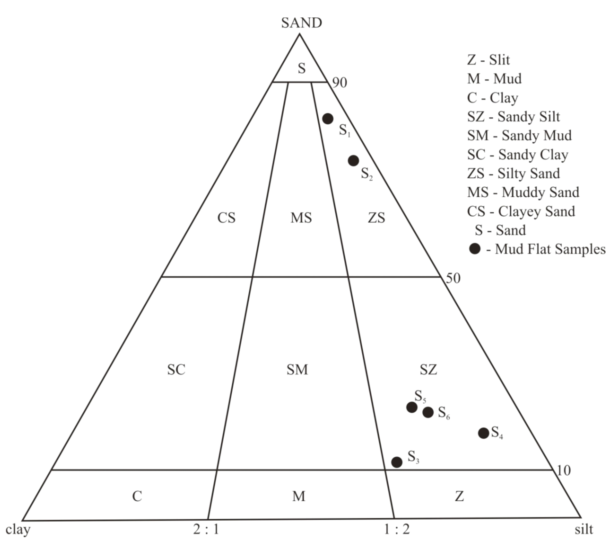

Fig. 5. Triangular Diagram Showing Classification of Mudflat (sand-silt-clay) samples from Shastri Estuary

(Fig. 6a, b and c) and clay mineral assemblages identified (Table 3).

Infrared Spectroscopic Studies

I. R. spectroscopic study of these mud samples was also carried. IR spectra for all six samples were obtained on a Perkin-Elmer model 783 Infra-Red spectrophotometer and interpreted (Fig. 7a, b and c) for mineral content (Table 4).

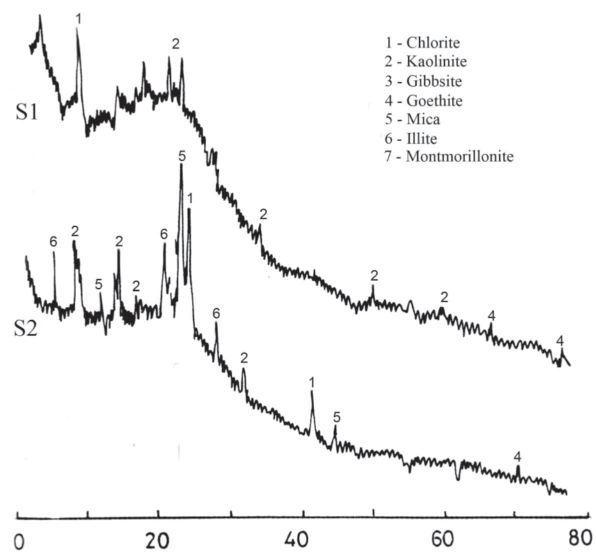

Fig. 6a. X-Ray Diffractograms of Mud Samples of Shastri Estuary (Lower reach)

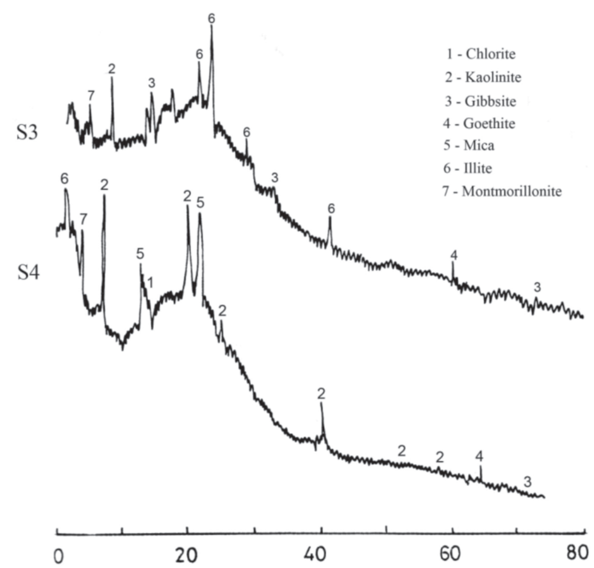

Fig. 6b. X-Ray Diffractograms of Mud Samples of Shastri Estuary (Middle reach)

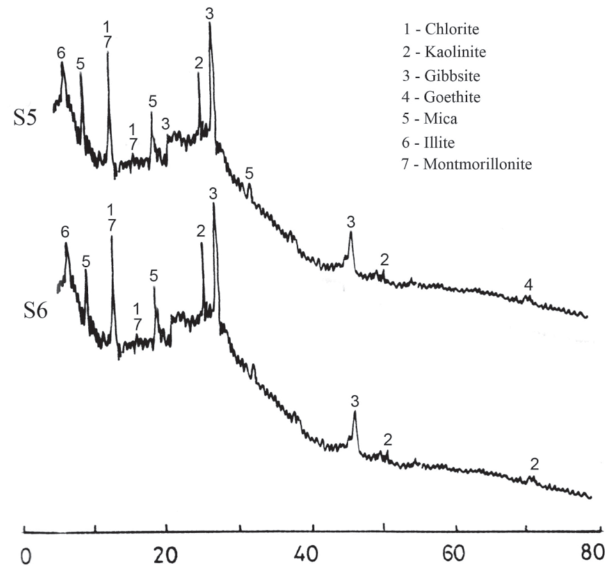

Fig. 6c. X-Ray Diffractograms of Mud Samples of Shastri Estuary (Upper reach)

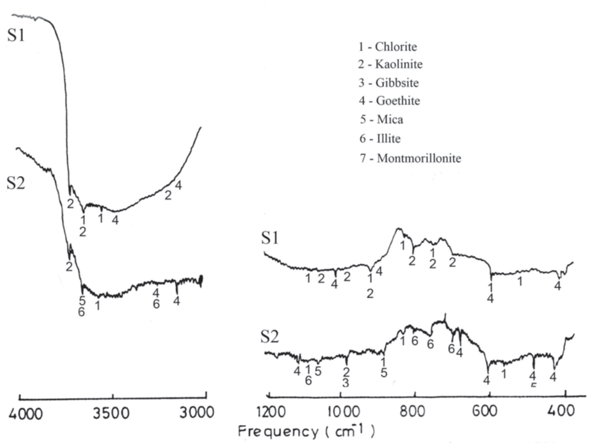

Fig. 7a. Infra-Red Spectra of Mud Samples Shastri Estuary (Lower reach)

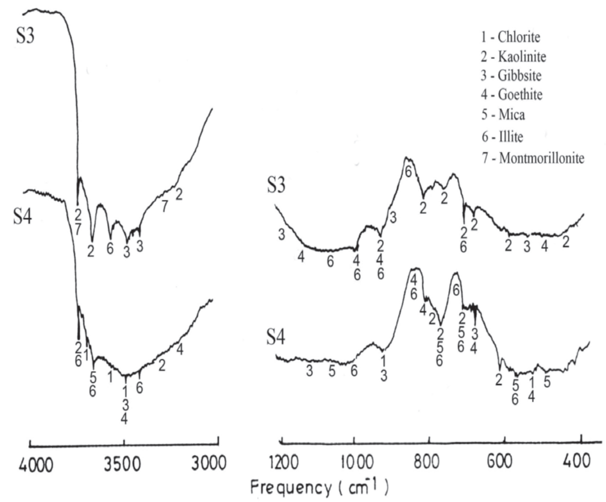

Fig. 7b. Infra-Red Spectra of Mud Samples Shastri Estuary (Middle reach)

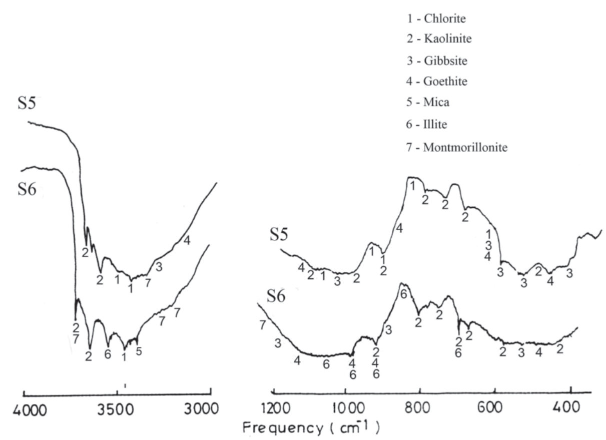

Fig. 7c. Infra-Red Spectra of Mud Samples Shastri Estuary (Upper reach)

Conclusion and Discussion

From the insoluble residue analysis, it has been observed that water-soluble salts are negligible in

Table 4. Clay mineral assemblages interred from X.R.D. and I.R. for mudflat samples of Shastri Estuary

Sample No.	X.R.D.	I.R.
S-1	Kaolinite, Goethite, Chlorite	Kaolinite, Goethite, Chlorite
S-2	Kaolinite, Goethite, Chlorite, Illite, Muscovite	Kaolinite, Goethite, Chlorite, Illite, Muscovite
S-3	Kaolinite, Goethite, Illite, Gibbsite, Montmorillonite	Kaolinite, Goethite, Illite, Gibbsite, Montmorillonite
S-4	Kaolinite, Goethite, Illite, Muscovite, Gibbsite	Kaolinite, Goethite, Illite, Muscovite,
S-5	Kaolinite, Goethite, Chlorite, Muscovite, Gibbsite, Montmorillonite	Kaolinite, Goethite, Chlorite, Muscovite, Gibbsite, Montmorillonite
S-6	Kaolinite, Chlorite, Illite, Muscovite, Gibbsite, Montmorillonite	Kaolinite, Chlorite, Illite, Muscovite, Gibbsite, Montmorillonite

quantity than acid soluble salts in all samples. The low content might be due to the absence of biological activities at the time of deposition of these sediments while, the presence of acid soluble fractions might be due to deposition of carbonates during post depositional phase.

Significant number of fines with < 63 ìm size are present in sediments. From the grain size analysis, it has been observed that the percentage of coarser fraction is maximum in the samples from lower reaches, near the mouth of the estuary. It might be due to active hydrodynamic conditions facilitating the deposition of sand fractions near the mouth. Presence of finer fractions are maximum in the middle reaches, might be due to the release of the fine sediments by tributaries in the Shastri river. From the plots on triangular diagram, the sediments from mouth of estuary can be classified as silty-sand whereas the sediments from middle and upper reach can be classified as sandy-silt.

The X-ray diffraction and IR Spectroscopic studies show presence of clay minerals like kaolinite, montmorillonite, illite along with muscovite, chlorite, goethite, gibbsite minerals. Presence of particular clay mineral is an indication of the degree and extent of chemical weathering of the host rock i.e., basalt under humid and subtropical conditions (Suryavanshi, *et al.,* 2014) The process of laterization of basalt involves leaching of the most of the oxides from pyroxenes and feldspars. It seems that leaching process is responsible for the formation of clay minerals in the residual deposit. It is a primary environment in the area in which the clay minerals are formed. These clay minerals might have transported from laterites through lithomarge clay to the mud flats and deposited along the banks of estuarine mouth and hinterland zones, representing a secondary environment.

According to Biscay, (1965), the formation and presence of kaolinite in the mudflats takes place due to intense chemical weathering of the plagioclase feldspars from the basaltic soils developed under heavy rainfall, good drainage and acidic water. In marine environment, kaolinite concentrates near the shore (Keller, 1970). Kaolinite is weathering product of feldspar and other silicates, produced by ion stripping in power pH environment. (Saha, *et al.,* 2020) Presence of kaolinite in the mudflat of Shastri might be due to its deposition under estuarine environment.

Presence of illite from transitional environment along estuaries of Maharashtra coast have been reported by Pandian and Sukhtankar (1991). Kaolinite, when subjected to subsequent digenesis during burial of sediments, gives rise to illite + chlorite (Velde, (1968). When fluvial system discharges kaolinite into ocean, it probably begins to dissolve under the influence of marine environment with the formation of illite (Keller, 1970)

Montmorillonite clay also shows its genesis in the primary environment like that of kaolinite, from laterite and lithomarge clay. It might have been transported through the major stream at the time of deposition. It is formed due to intense chemical weathering of volcanic material (Keller, 1970). According to Kenett, (1982), formation of montmorillonite takes place from the basaltic flows or from laterites. Its abundance depends on the hydraulic conditions of the estuarine environment (Grim, 1968). Along the Shastri estuary, presence of higher percentage of kaolinite as compared to montmorillonite might be due to the estuarine environment.

Presence of Gibbsite in the mud flats indicate its formation by breaking away of the feldspars from basalt (Khanadal and Devraju, 1987). It might also be formed due to chemical weathering of kaolinite. With the increasing degree of leaching, kaolinite gets transferred to gibbsite by a hydrolysis process (Jackson, 1959; Velde, 1985). The presence of kaolinite, gibbsite along with goethite indicate their formation under intense chemical weathering of pyroxene i.e. augite present in the Deccan basalts (Sahastrabudhe, 1989).

Chlorite and muscovite minerals are reported in less number in mud flats of the Shastri estuary. Formation of chlorite might be due to digenetic alteration of kaolinite or gibbsite.

Muscovite is flaky in habit and has relatively less specific gravity. It can easily migrate through medium of water. It might have formed by the hydrothermal alteration of pyroxenes present in the Deccan basalts or due to longshore transport, being derived from the Precambrian terrain, exposed in the southern part of the study area.

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