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Origin and occurrence of clay minerals in the Ariyalur Group of sedimentary rocks, Cauvery basin, Tamil Nadu, India

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ABSTRACT

Clay mineral assemblages in the Ariyalur Group of sedimentary rocks were studied by X-ray diffraction analysis. The results of the study indicate that illite and smectite are the predominant clay minerals whereas kaolinite and chlorite occur in minor amounts. The Campanian-Lower Maastrichtian rocks (i.e., Sillakkudi and Kallankurichchi Formations) contain a large amount of illite. The study reveals that these sediments were derived from the continental erosion of pre-existing rocks that were subjected to low intensity chemical weathering associated with a temperate climate. A significant decrease in illite content is observed in the Ottakkovil Formation. It implies a climatic transition (from temperate to warm) during the Middle Maastrichtian time. On the other hand, a high content of pedogenic smectite in the Kallamedu Formation is indicative of warm climatic conditions with alternating dry and wet periods during the formation of this mineral.

INTRODUCTION

The Cauvery Basin lies in the East Coast of India. It consists of a thick (5-6 km) pile of syn-rift (more than1000 m) and post-rift (about 5 km) sedimentary rocks resting over the basement (Rangaraju et al. 1993). The Cretaceous rocks in the Cauvery Basin occur as five isolated patches in the western margin fringing the Archaean basement.

The sedimentary rocks exposed in the Trichinopoly area were studied in detail by many workers (e.g., Sastry et al. 1972, Nair 1974, Banerji 1979, Ramanathan 1979, Sahni 1982, Kumar 1983, Sundaram and Rao 1986, Ramasami and Banerji 1991, Govindan et al. 1996) for stratigraphy, palaeontology and tectonic evolution. Blanford (1862) was the first to work out the detailed stratigraphy. He distinguished the Uttatur, Trichinopoly, and Ariyalur Groups. Among them, the Ariyalur Group (unconformably resting over the Trichinopoly Group) covers an extensive area and also has the greatest vertical thickness.

The study area is located between 10°56' and 11°21' N Latitudes and 78°56' and 79°15' E Longitudes (Fig. 1). In the area, significant facies variations are observed up to the Palaeocene owing to the tectonic events onshore or in the basin itself (Ramanathan 1979, Sahni 1982, and Kumar 1983).

Clay minerals are formed by detrital, inheritance, transformation, and neoformation processes (Chaudhri and Kalitha 1985). Variations in the clay mineralogy may result from modifications in the detrital provenance related to tectonics (Chamley 1989) but also from changes of the weathering intensity or variations in depositional conditions depending on climatic conditions (Schieber 1986). This study was undertaken to understand the distribution, occurrence, and geological significance of clay mineral assemblages in various lithological units of the Ariyalur Group.

LITHOLOGY AND STRATIGRAPHY

Sastry et al. (1972) subdivided the Cretaceous rocks of the Ariyalur Group in the Tiruchirapalli area into the Sillakkudi, Kallankurichchi, Ottakkovil, and Kallamedu Formations. The Sillakkudi Formation comprises calcareous sandstone, gritty sandstone, arkosic sandstone, sandy clay and thin bands of

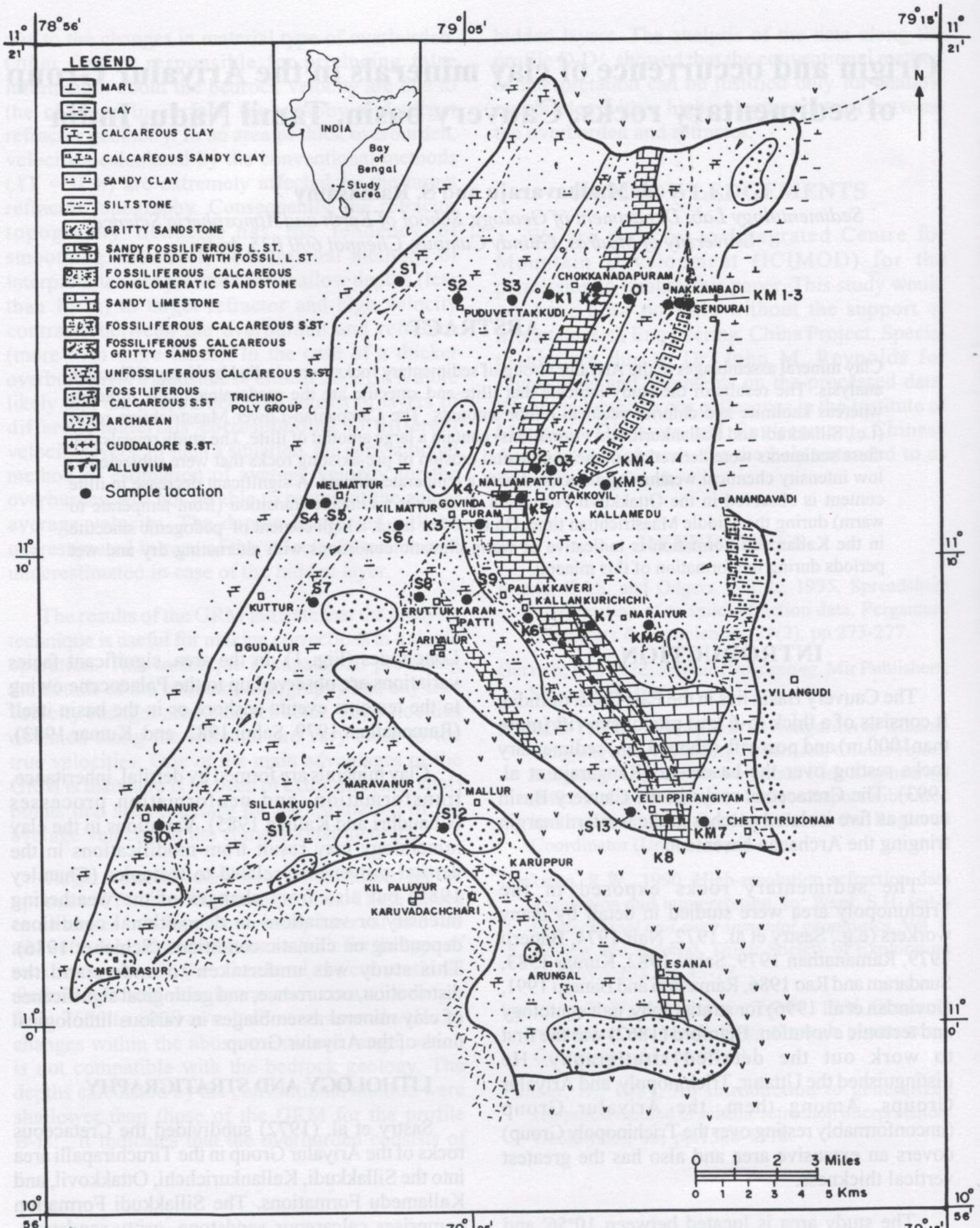

Fig. 1: Geological map showing sample locations

limestone. The succeeding Kallankurichchi Formation is made up essentially of limestone bodies with minor clastic deposits (calcareous conglomeratic sandstone, calcareous sandstone, and sandy clay). The Ottakkovil Formation is composed of buff coloured calcareous sandstone and sandy clay. These three formations were deposited in the marginal marine environment (Suyndaram and Rao 1986). The Kallamedu Formation, the youngest of the Group, consists of argillaceous sandstone and ferruginous claystone deposited in marshy and fluvial environments (Madhavaraju 1996). The argillaceous sandstone of the Kallamedu Formation contains dinosaurian remains, which further support the existence of a marshy environment during the deposition of its lower part.

MATERIALS AND METHODS

Clay-rich samples of various lithological units were collected along the representative traverses mostly in the general dip direction (E to SE) of the Ariyalur Group. Clay mineralogical studies were carried out by using standard XRD procedures (Grim 1968, Biscay 1965, Muller 1967, Hardy and Tucker 1988). Thirty-one oriented and glycolated samples from the Sillakkudi, Kallankurichchi, Ottakkovil, and Kallamedu Formations were analysed for identification of clay minerals. For the determination of bulk mineralogy, fifteen powdered bulk samples (unoriented) were selected. The bulk samples were scanned from 2° to 50° (2θ) and oriented and glycolated slides were scanned from 2° to 30° (2θ) in X-ray diffractometer using CuKα radiation at 30 kV and 20 mA with scanning speed of 2° (2θ) per minute.

QUALITATIVE MINERALOGY FROM X-RAY STUDY

Qualitative mineralogy of the clay samples was determined with the standard interpretation procedures of XRD data (Biscay 1965, Grim 1968, Brindley and Brown 1980). The identified non clay minerals were quartz, feldspar, calcite, and muscovite (Fig. 2). The important clay minerals identified through X-ray diffraction study were illite, smectite, kaolinite, and chlorite (Fig. 2).

SEMI-QUANTITATIVE ANALYSIS OF CLAY MINERALS

Semi-quantification of clay minerals was done following the procedure given in the second method of Pierce and Siegel (1969). The intensity of the 17 Å glycolated peak is equal to the relative amount of smectite. Illite is calculated from the 10 Å glycolated peak and multiplied by a factor of four whereas the 7 Å oriented peak area is multiplied by two for the relative amount of kaolinite+chlorite.

The Sillakkudi and Kallankurichchi Formations showed a high (70 - 83%) content of illite whereas a significant depletion (45 - 50%) was recorded in the Ottakkovil Formation, while the Kallamedu Formation revealed a low (26 - 31%) content of illite. The illite content decreased towards the stratigraphically younger formations. Conversely, a low (15 - 24%) content of smectite was found in the Sillakkudi and Kallankurichchi Formations, a moderate (32 - 37%) content of smectite was recorded in the Ottakkovil Formation, whereas a high (58 - 63%) content was found in the Kallamedu Formation. Smectite showed an increasing trend towards the younger formations and was negatively correlated with the illite content. All other formations except for the Ottakkovil Formation, showed the least content of kaolinite and chlorite minerals. The Ottakkovil Formation contained from 15 to 18% of kaolinite and chlorite while they constitute from 2 to 12% in the other formations. The distribution of clay minerals in various formations is given in Table 1.

CONCLUSIONS AND DISCUSSION

The fine-grained sequence of the Ariyalur Group is enriched in illite and smectite whereas kaolinite and chlorite are present in small proportions (Fig. 3). Illite is predominant in the Sillakkudi and Kallankurichchi Formations whereas it is depleted across the Ottakkovil and Kallamedu Formations. The kaolinite+chlorite content ranges from 2 to 18%. As kaolinite and chlorite are present in a small amount (as compared with other clay minerals), they have no significance for the environmental interpretation of the Ariyalur Group.

The diagenetic illitisation of smectite requires a burial depth of more than 1500 m but the petrographic analysis revealed shallow burial diagenesis

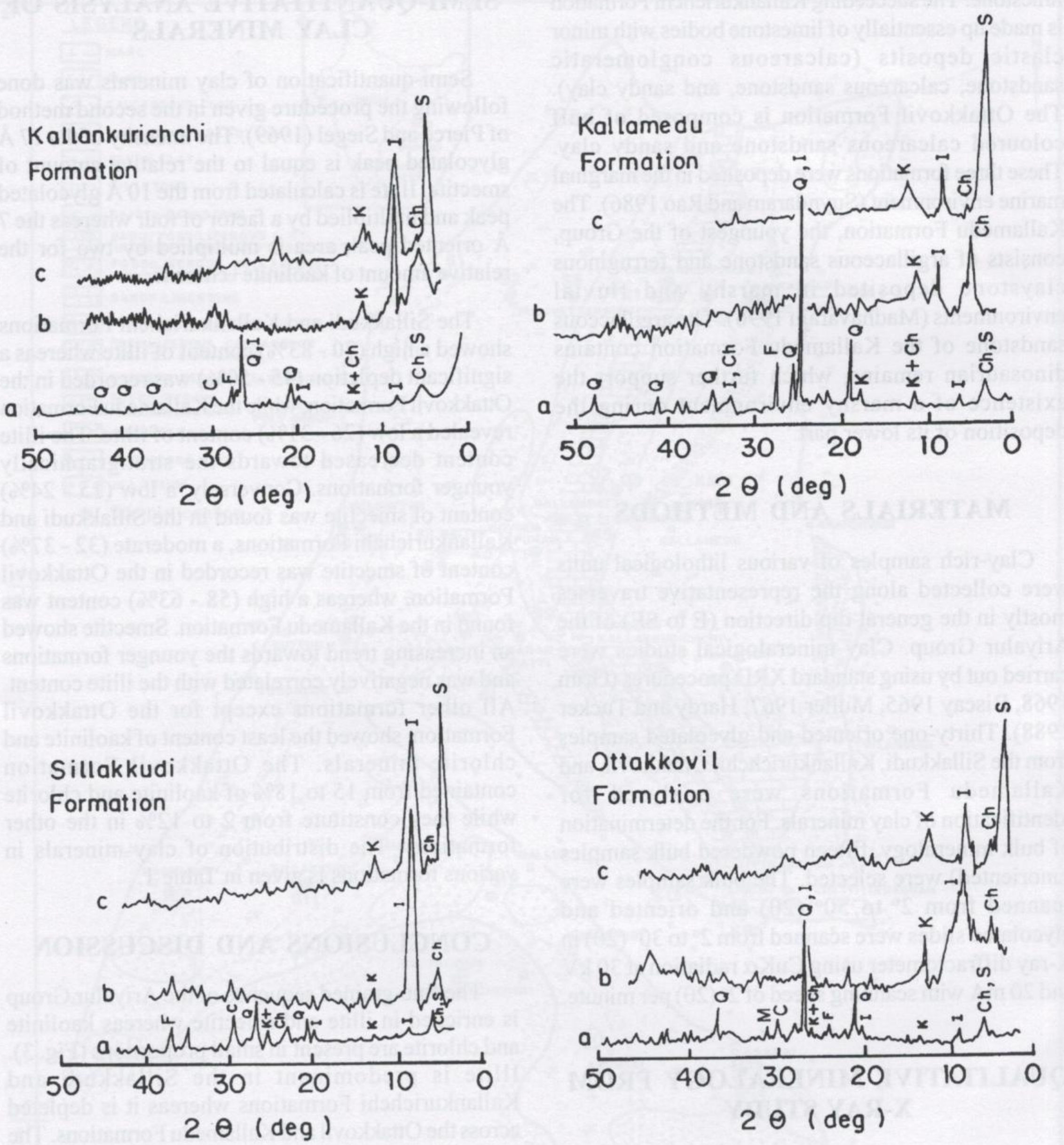

Fig. 2: X-ray diffractograms of selected clay rich samples from the Ariyalur Group

(Madhavaraju 1996). The absence of identifiable diagenetic changes suggests that these sediments were not subjected to a deep burial.

On the other hand, the source rock modification could also have lead to the mineralogical changes. In order to discriminate the climatic changes from the source rock modification, a study on trace and REE geochemistry of the sedimentary rocks was undertaken. The REE study revealed the LREE enriched and HREE depleted patterns, which further suggest the felsic nature of the source rock

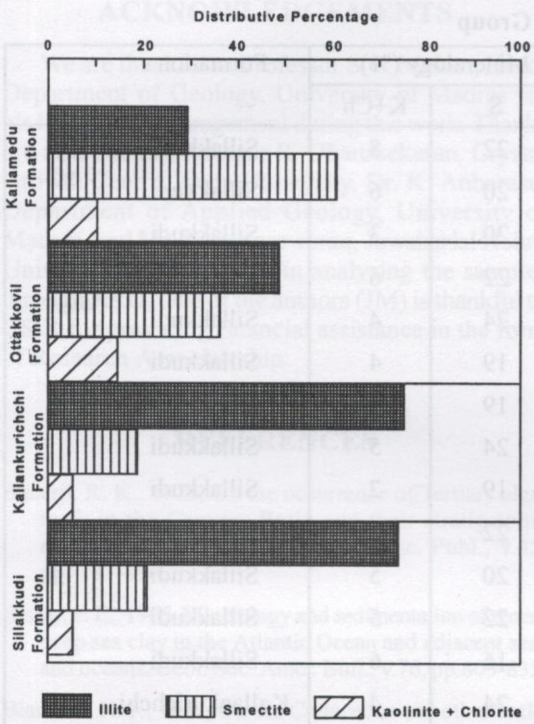

Fig. 3: Distributive percentage of clay minerals in the Ariyalur Group

(Madhavaraju 1996). All the four formations showed a uniform REE pattern and there was no significant variation in elemental ratios (trace and REE) indicating that these sediments were derived from a homogenous source (Madhavaraju and Ramasamy 1998). Hence the variation in clay mineral assemblages in the Ariyalur Group was influenced by the climatic conditions in the source region rather than changes in the provenance. The qualitative and quantitative variations of clay associations were controlled essentially by the environmental conditions on exposed landmasses and the mechanism of transport (Chamley et al.1993).

Illite is one of the early products of weathering of feldspathic and micaceous rocks and is stable under moderate climatic conditions (Chaudhri and Kalitha 1985). The high content of illite is suggestive of temperate environment where weathering has not been intense (Foth and Truck 1973). The occurrence of illite in Sillakkudi and Kallankurichchi Formations could be due to the increase in the supply of detrital illite from the source area. The high illite content indicates that the chemical weathering dramatically decreased during the Campanian-early Maastrichtian times.

The decreasing supply of rock-derived minerals (i.e. illite, kaolinite, and chlorite) balanced by the increasing supply of pedogenetic smectite in the Ottakkovil Formation can be attributed to the onset of climatic warming during the middle Maastrichtian time. It is not easy to separate the climatic and tectonic influences on clay sedimentation (Fagel et al. 1992). The general increase of the smectite abundance towards the younger lithological units (i.e. the Ottakkovil and Kallamedu Formations) and the corresponding decrease of illite abundance were documented in this study. The formation of pedogenic smectite was common in the late Cretaceous time (Chamley 1989, Diester-Haas et al. 1993). The global trend is often attributed to an increasing supply of pedogenic minerals (smectite) balanced by a decreasing supply of rock-derived minerals (illite), determined by the climatic warming during the late Cretaceous. It is inferred that the high proportion of smectite was derived from pedogenesis on the exposed margin of the study area. Pedogenic smectite was principally developed in warm continental areas of low relief where periodic water spreading during wet seasons favoured the accumulation of chemical elements, and subsequent evaporation during the dry seasons lead to a rapid mineralogical evolution resulting in the smectite development (Paquet 1970, Gac 1980, Diester-Haass et al. 1993). Significant depletion in illite content and increase in smectite content in the Ottakkovil formation indicate that the climatic changes i.e. from temperate to warm climatic conditions (subtropical climate) had occurred during the mid-Maastrichtian time. The observed climatic changes were influenced by the northward drift of Indian plate bringing the Cauvery Basin under the influence of warm tropical water mass (Govindan and Narayanan 1980, Herb and Scheibnerova 1977).

During the late Maastrichtian time, relatively more smectite was deposited in the Kallamedu Formation. It was a warmer period with alternating dry and wet conditions, where smectite genesis due to chemical weathering depressed the illite percentage.

Table 1: Distribution of clay minerals in the Ariyalur Group

S.N.	Sample number	Type of sediments	Clay Mineralogy (%)			Formation
			I	S	K+Ch	
1	S1	Sandy clay	70	22	8	Sillakkudi
2	S2	Silty clay	74	20	6	Sillakkudi
3	S3	Sandy clay	77	20	3	Sillakkudi
4	S4	Sandy clay	72	22	6	Sillakkudi
5	S5	Sandy clay	72	24	4	Sillakkudi
6	S6	Sandy clay	77	19	4	Sillakkudi
7	S7	Sandy clay	75	19	6	Sillakkudi
8	S8	Sandy clay	71	24	5	Sillakkudi
9	S9	Sandy clay	79	19	2	Sillakkudi
10	S10	Sandy clay	70	22	8	Sillakkudi
11	S11	Sandy clay	75	20	5	Sillakkudi
12	S12	Sandy clay	73	22	5	Sillakkudi
13	S13	Sandy clay	78	16	6	Sillakkudi
14	K1	Sandy clay	72	24	4	Kallankurichchi
15	K2	Sandy clay	81	17	2	Kallankurichchi
16	K3	Sandy clay	74	16	10	Kallankurichchi
17	K4	Sandy clay	79	18	3	Kallankurichchi
18	K5	Sandy clay	79	15	6	Kallankurichchi
19	K6	Silty clay	76	21	3	Kallankurichchi
20	K7	Sandy clay	80	18	2	Kallankurichchi
21	K8	Sandy clay	72	21	7	Kallankurichchi
22	O1	Sandy clay	45	37	18	Ottakkovil
23	O2	Sandy clay	50	37	13	Ottakkovil
24	O3	Sandy clay	52	35	13	Ottakkovil
25	KM1	Sandy clay	28	62	10	Kallamedu
26	KM2	Silty clay	31	63	6	Kallamedu
27	KM3	Silty clay	30	60	10	Kallamedu
28	KM4	Sandy clay	27	63	10	Kallamedu
29	KM5	Sandy clay	30	58	12	Kallamedu
30	KM6	Sandy clay	30	62	8	Kallamedu
31	KM7	Silty clay	26	62	12	Kallamedu

I - Illite S - Smectite K+Ch - Kaolinite + Chlorite

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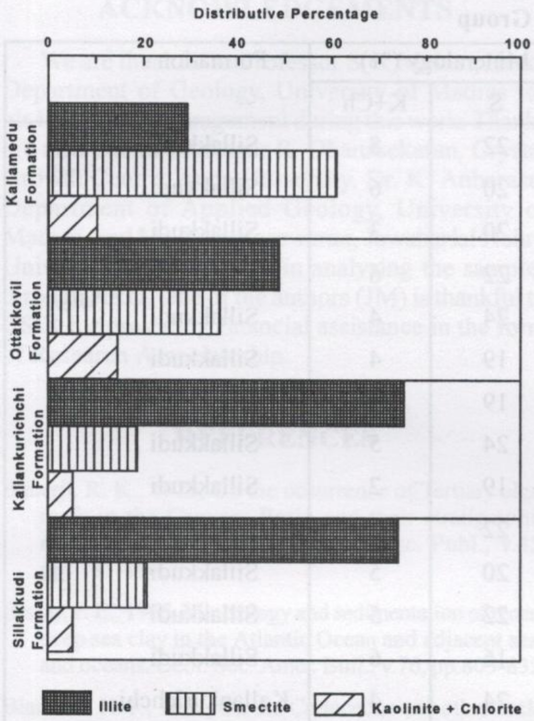

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