PI438489B, PI404198B, PI438503A, PI89772, PI404166, PI437908, PI209332 and PI437655. The resistance genes in these PIs will be mapped.

The results showed that greater diversity for markers existed among the PIs than the two cultivars used in this study. The two cultivars Essex and Hutcheson were also clustered away from the PIs in the dendrogram (Figure 1). This is expected, because the PIs are in general a diverse group of accessions collected in Asia and South America, whereas the cultivars were derived from a limited number of PIs introduced in USA at the turn of the century. In this study, no relationship was found in general, between geographical origin of PIs and the clusters obtained based on the limited number of probes used, but some degree of relationship was observed for spectrum of resistance. Both PI424595 and PI437908 susceptible to races 3 and 14 which clustered at the lower end of dendrogram have originated from South Korea.

Our study has demonstrated that an analysis of RFLP markers can be used to determine genetic relationships among PI lines of soybean. In the absence of typical pedigree information, DNA fingerprinting should be most useful in establishing their genetic relationship to develop appropriate populations for gene mapping studies.

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Aeolian deposition of Arabia and Somalia sediments on the southwestern continental margin of India

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Kaolinite, smectite, illite and chlorite as major clay minerals and palygorskite and gibbsite in minor quantities have been recorded from the slope of southwestern continental margin of India. Contribution of kaolinite, smectite and gibbsite is from peninsular India through fluvial discharge. Since formation of palygorskite calls for an arid and hot climate and saline conditions, occurrence of this clay mineral in the sediments of the study area documents aeolian sediment contribution from Arabia and Somalia by the Arabian northwesterly winds.

STUDIES of marine clays are a significant tool to determine sources, sediment dynamics and environment of deposition[1–4]. The climate and geology of the source area[3] largely dictates the type of clay species supplied. By and large, characteristic clay minerals of different climatic and geological settings have been identified[1,3].

Studies of clay mineral variations in the western continental margin of India mainly suggest two important sources of the clays. Illite and chlorite are reported to be mostly contributed by the Indus River and the low salinity Bay of Bengal Waters (BBW), intruding into the southwestern continental margin during November–January[5–11]. Kaolinite, gibbsite and smectite (and minor amounts of illite) are produced due to intense chemical weathering of Indian subcontinent, and are contributed from the adjacent landmass[5–7]. Two contrasting opinions exist about the dispersal of these clay minerals. Ramaswamy and Nair[9] have reported a lack of cross-shelf sediment transport and have suggested an along shelf transport of the sediments brought by the major fluvial routes of the Indian subcontinent. Others[7,12] proposed across-shelf transport of the sediments and clays and suggested the influence of the climate and the geology of the western continental margin of India on local clay mineral distribution. But, aeolian supply from other continents has not yet been documented.

The present work was carried out between Cape Comorin and Quilon (Figure 1). Clay mineral studies of 51 surface sediment samples are the basis of the present study. Sediment contribution by the aeolian processes to the northwestern and the central Arabian Sea, adjacent to Somalia and Arabia, has been documented[5–11]. The present work records sediment contribution by the aeolian process to the southwestern continental margin of India.

During the 158th cruise of *R. V. Gaveshani*, 51 surface sediment samples along and across 7 transects, spread between 7.0°–9.56°N and 75.35–78.0°E, were collected using a Peterson grab (Figure 1). The samples were washed to remove salts, oven dried at 70°C and were analysed for texture. Pipette separated, < 2 μm, oriented, and air-dried samples were subjected to X-ray diffraction studies on a Philips diffractometer (model PW 1814) using a nickel filtered CuK_α radiation ($\lambda = 1.54$). Standard glycolation methods[13] were used to aid the identification of expandable clay minerals. Weighted peak area method[1] was used to quantify the clay species. Palygorskite is identified by slow scanning (rate 0.6 2 θ min^{-1}) between 8 and 20° to resolve its principal peaks at 10.4 Å, 6.36 Å and 4.47 Å, and quantified after the method of Sirocko and Lange[11]. To check the reliability of analysis, about 20% of samples were reanalysed which revealed ± 8% accuracy for smectite and ± 5% for other clays.

The major clays observed in the study area are kaolinite, smectite, illite and chlorite in the order of abundance (Figure 2). Others present in minor amounts are gibbsite (~ 5%) and palygorskite (5–8%) (Figure 2). Occurrence of palygorskite (Figure 1) suggests a wide distribution of this clay mineral in the samples. Smectite content (range 42.97–19.94%), generally, shows an offshore-increasing trend (content > 35%), whereas kaolinite content is high (generally 35–40%; at some locations > 40%) along the slope, and off the Karmarna River (Figure 1). Though, on the upper slope illite (15–25%) and chlorite (10–13%) are generally low, along the entire lower slope their contents were found to be higher (illite 25–35% and chlorite > 15%; Figure 1). Gibbsite (~ 5%) is distributed over the slope region. The results also indicate an absence of < 45 μm size detritus on most of the shelf helping to define a 'no clay zone' (Figure 1).

The climate in the adjacent landmass of the study area is humid tropical – rainfall ranges between 280 and > 400 cm in the inland areas of Western Ghats[14,15]. The clays reported[16–17] from the soil of the hinterland are kaolinite and smectite in major quantities with traces of gibbsite. Four small rivers, rising in the Western Ghats (Figure 1) dump their load in this area. The sediments of mud banks and estuarine region (located north of the study area) are reported to have kaolinite and smectite with illite in minor amount[18].

There is a general offshore-increasing trend in the abundance of smectite and kaolinite clays (Figure 1). Owing to the high content of smectite at the southwestern continental margin, Kolla *et al.*[5] suggested its possible derivation from the Bay of Bengal Waters (BBW). But, illite (80%) and chlorite are the most important constituents of the BBW[4,19–22]. Smectite too is reported from the adjacent landmass and estuarine sediments[16,17], and its content shows more pronounced variations across the slope (< 20% on the upper slope to > 30% in the lower slope) without any reduction in its abundance (~ 30%) along the slope, particularly in the northerly direction corresponding to the movement of BBW (Figure 1). It is, therefore, suggested that smectite and kaolinite with similar sources and distribution trends, are mainly contributed by the local river discharge and dispersed across-shelf. The presence of gibbsite, forming under humid climate from the weathering in the hinterland[3], further corroborates across-shelf transport of the sediment derived from peninsular India. Deposition of illite and chlorite along the southwestern continental margin of India by the low salinity BBW, entering this region

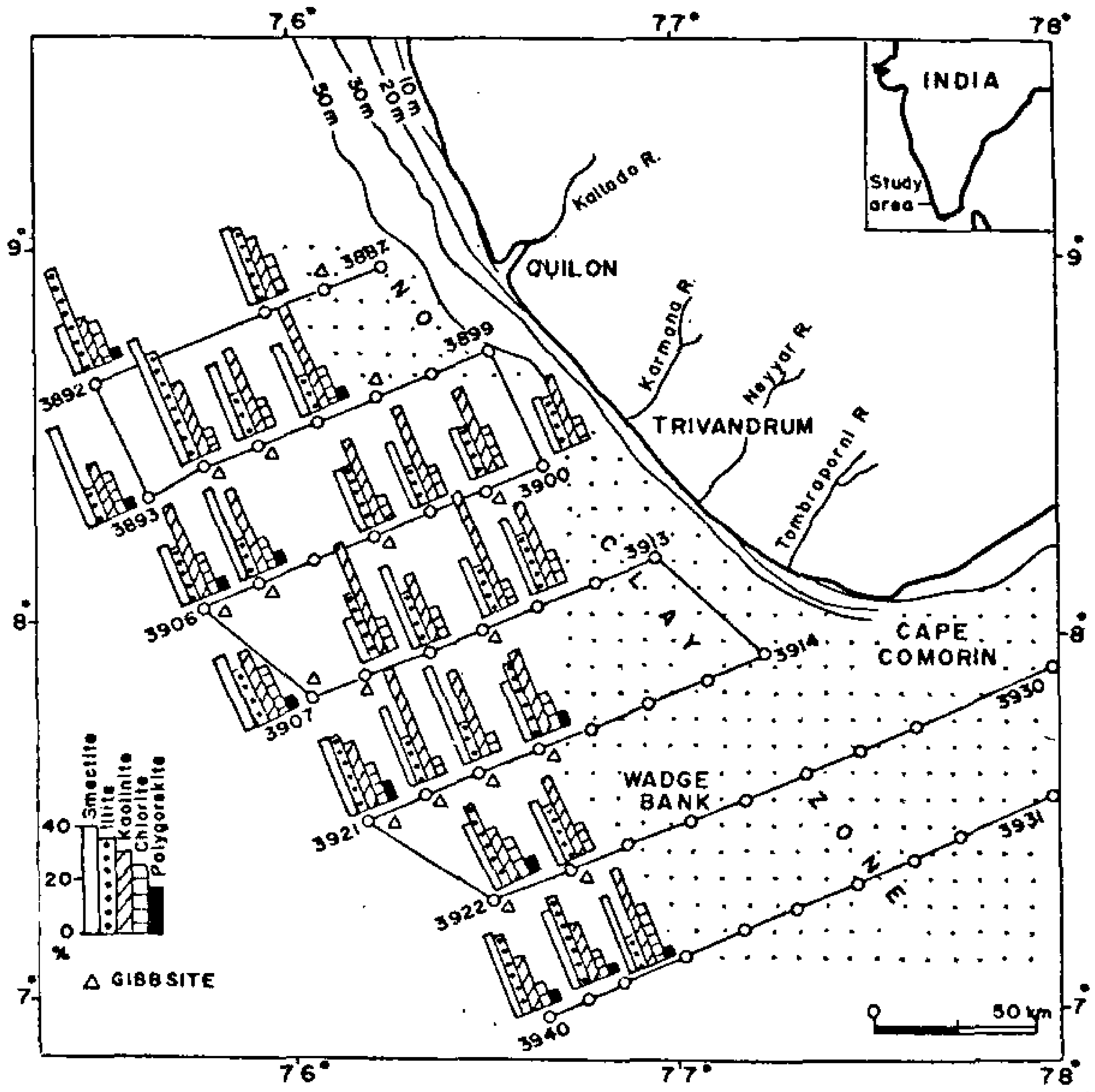

Figure 1. Sampling site, sea bottom physiography and distribution of clays in the sea bed. Note 'No clay zone' in the shelf, and enrichment of kaolinite and smectite on the slope. Distribution of palygorskite in the study area is also shown.

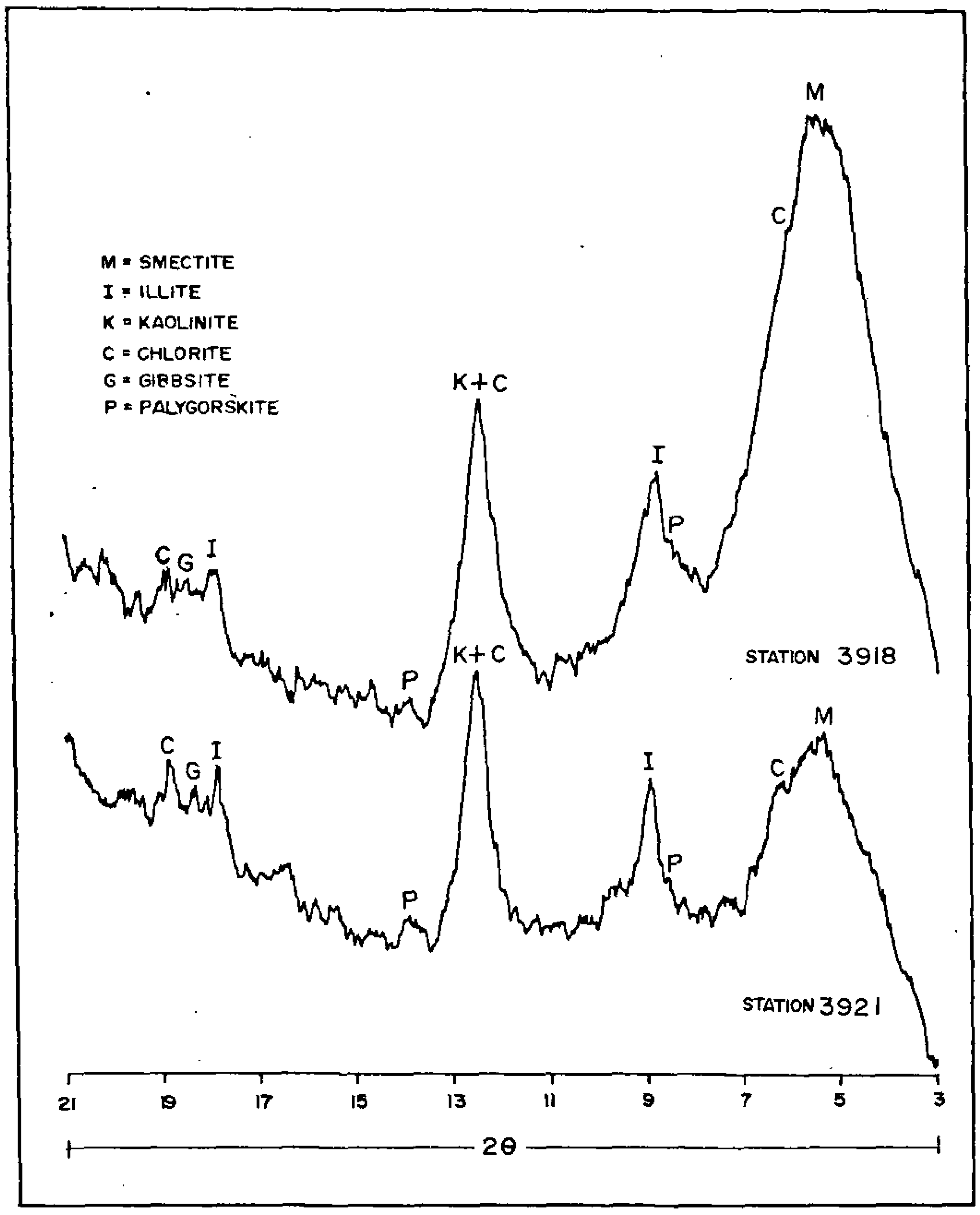

Figure 2. X-ray diffractograms of the sediments from the study area. See Figure 1 for the location of the samples.

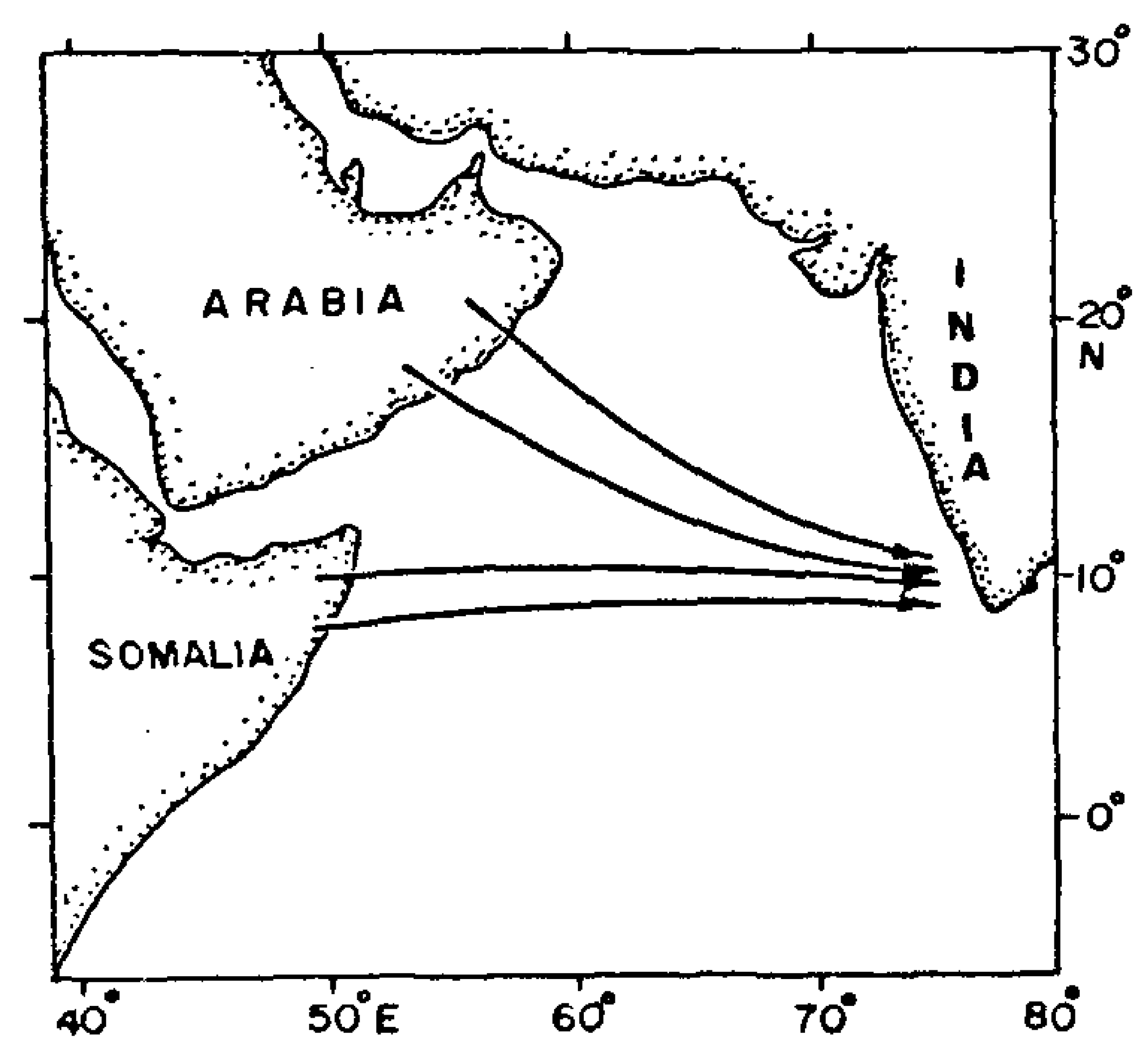

Figure 3. Path of the wind from Arabian peninsula and Somalia.

during November–January[23–24], has already been documented[10].

Palygorskite has not been reported from either soil or estuarine sediments though it has been observed over a sizeable area along the slope (Figure 1). Formation of palygorskite requires saline, semi-arid and hot climate with changes in groundwater level[11]. Since climate of the hinterland is humid-tropical, formation of palygorskite in this area and its supply from this source appears to be very unlikely. The presence of palygorskite along the slope, therefore calls for a non-local source.

Suitable saline, semi-arid, and hot climate with changing groundwater levels do prevail in the Sebkha and Wadi regions of Arabia[11]. Palygorskite is also reported from the Mesozoic rocks of the Arabian peninsula and part of Somalia[11]. In the northwestern and the central Arabian Sea, adjacent to the Arabia and Somalia, content of palygorskite is generally ~ 10%, which decreases southeasterly and has been attributed to southeasterly dispersal by winds[5,6,11].

From Red Sea to Persian Gulf, the Arabian northwesterly winds prevail throughout the year. Aerosol content of these winds is high[25,26] (3000 $\mu g/m^3$) and satellite imageries indicate that this dust spreads over the southwest monsoon trajectories in the mid troposphere[11,27] and its extension has also been observed as far away as south Indian coast[28]. Palygorskite, besides illite and smectite, is present as one of the significant constituents in the aerosol dust samples[29,30]. These winds and trajectories of southwest monsoon winds are reported to be the carrier of palygorskite to the northwestern Arabian Sea[11]. Therefore, in the absence of any local source, and from the foregoing evidences and the satellite data[28], it is deduced that the main source of palygorskite lies in Arabia and Somalia. Further, southeastward transport of aerosol dust by Arabian northwesterly winds (as shown in Figure 3) contributes palygorskite to the southwestern continental margins of India.

In the shelf region, a 'no clay zone' has been observed (Figure 1). The prevalent environmental conditions, i.e. high magnitude currents, a large riverine discharge due to heavy rainfall in the catchment areas, and steep river gradient are reported to have inhibited the deposition of the fine silty-clayey particles on the shelf[10]. The absence of palygorskite in the shelf, therefore, does not necessarily indicate a weak aerosol source but reflects the role of hydrography which preludes the deposition of fines in the shelf.

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Microstructural evidence for the formation of crenulation cleavage in rocks

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The mica domains of crenulated schists belonging to the Lunavada group of Precambrian rocks in Gujarat show microstructures similar to Schistosité–Cissilament fabric and extensional crenulation cleavage which are features usually developed in rocks from ductile shear zones. While presenting a model illustrating the sequential development of crenulation cleavages and the observed microstructures within cleavage zones, it is suggested that during successive stages of formation of crenulation cleavage, solution transfer is dominant during the earlier stages whereas shearing is important during the later stages.

STRUCTURES such as Schistosité–Cissilament (S–C) fabric and extensional crenulation cleavage (ECC) are commonly known to develop in rocks in 'ductile shear zones' (DSZs)[1-6]. Such structures have also been produced in the laboratory[7,8]. They form because of a component of extension along a plane of anisotropy[2]. Here we give a description of the microstructures observed in the crenulated schists belonging to the Lunavada Group of Precambrian rocks in Gujarat. These show microstructures along cleavage zones which resemble the structures like S–C fabric and ECC found in DSZs. A model is given to explain their origin during the genesis of crenulation cleavage and the processes operating during different stages of crenulation cleavage development are discussed.

The Lunavada Group of Precambrian rocks occur in the Panchmahal district of Gujarat and parts of southern Rajasthan, India between 22°45′–23°45′ N and 73°15′–74°30′ E (Figure 1). It comprises alternating quartzites and mica schists and belongs to the Aravalli Supergroup[9-12]. Two episodes of deformation have been reported and the regional metamorphism is dominantly up to the greenschist facies[10-12]. The rocks are intruded by the Godhra granite. This has resulted in the superimposition of a thermal event over the regional metamorphic event due to heat supplied by the Godhra granite[13]. The present study deals with the microstructures observed in the mica schists.

Mica schists from Vankdi–Vena area lying 18 km east of Lunavada (Figure 1) possess large porphyroblasts of garnet and biotite and show a well developed differentiated crenulation cleavage (S_2). The differentiated crenulation cleavage is formed by microfolding of a pre-existing foliation S_1 and is defined by alternating quartz (Q) and mica (M) domains. Figures 2 *a*, *b*, *e* and *f* show a well-developed differentiated crenulation