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Surface Microtextures of Quartz Grains from the Central Coast of Tamil Nadu

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Abstract: Quartz grain surface micro textures of 12 samples collected from the beach were examined under scanning electron microscopy to understand the role of coastal processes on their transportation and deposition. The study area has been divided into three sectors on the basis of drainage, geomorphology and nature of the beach and shelf topography. Surface textures of the northern sector display an array of mechanical features like conchoidal fracture, V marks and impact pits, indicating the dominance of mechanical processes. However, silica precipitation in the form of globules indicates an added influence of chemical processes in the Northern sector. The presence of chemical features in northern sector, where energy level is high, corroborates the addition of quartz grains from paleo-sediments, from the nearby Tertiary and Cretaceous formations. Central sector quartz grains display the signatures of chemical and mechanical processes. The presence of step like furrows in southern sector is an indicator of fluvial low energy conditions, and supplements the role of littoral currents in depositing the quartz grains along the coastal region.

Keywords: Surface Texture, Quartz, SEM, Central Tamil Nadu coast.

INTRODUCTION

The surface microtextural study of quartz grains with the help of Scanning Electron Microscope (SEM) has proved to be an effective and useful tool in deciphering the depositional environments, the mode of transport and the digenetic processes of coastal, fluvial, glacial sediments. The different mechanical and chemical processes that affect quartz sand grains are apparent from the surface features (Al-Saleh and Khalaf, 1982). These features are described and catalogued according to depositional environment (Krinsley and Doornkamp, 1973). From the microtextures of Mesozoic – Cenozoic quartz sands from the Laborador and Greenland continental margins, the weathering climate and processes were deciphered (Higgs 1979). Significant contributions are made by Krinsley and Donahue (1968) and Krinsley and Margolis (1971) about quartz grain surface texture and their transport and depositional environment. Surface micro textures of quartz from consolidated sedimentary formation, mainly sandstone, and their implications on the depositional environment have largely been dealt with by many earlier workers (Madhavaraju and Ramasamy 1999; Madhavaraju et al. 2004). Micro textures of detrital quartz grains of alluvial sediments (Joshi, 2009) and marine transgressive formation (Madhavaraju et al. 2006) have also been studied. However, studies of similar kind on the detrital quartz grains from beaches and coastal landforms are scant. From the Indian coast, the micromorphology of quartz sand from beaches of Kerala (Mallik, 1992), coastal Southern Tamil Nadu (Cherian et al. 2004), and beaches of Goa (Ambre et al. 2005) are studied in detail. Barring these studies, scarcely any study has been undertaken on the surface micro textures of quartz grains from beach sediments. The present study aims to characterize the microtextures of quartz grains from central Tamil Nadu coast, which is marked by dynamic as well as static coastal processes.

STUDY AREA

The present study area is located in the Central coast of Tamil Nadu in Southern India and it is bordered on the East by Bay of Bengal (Fig.1). On the basis of

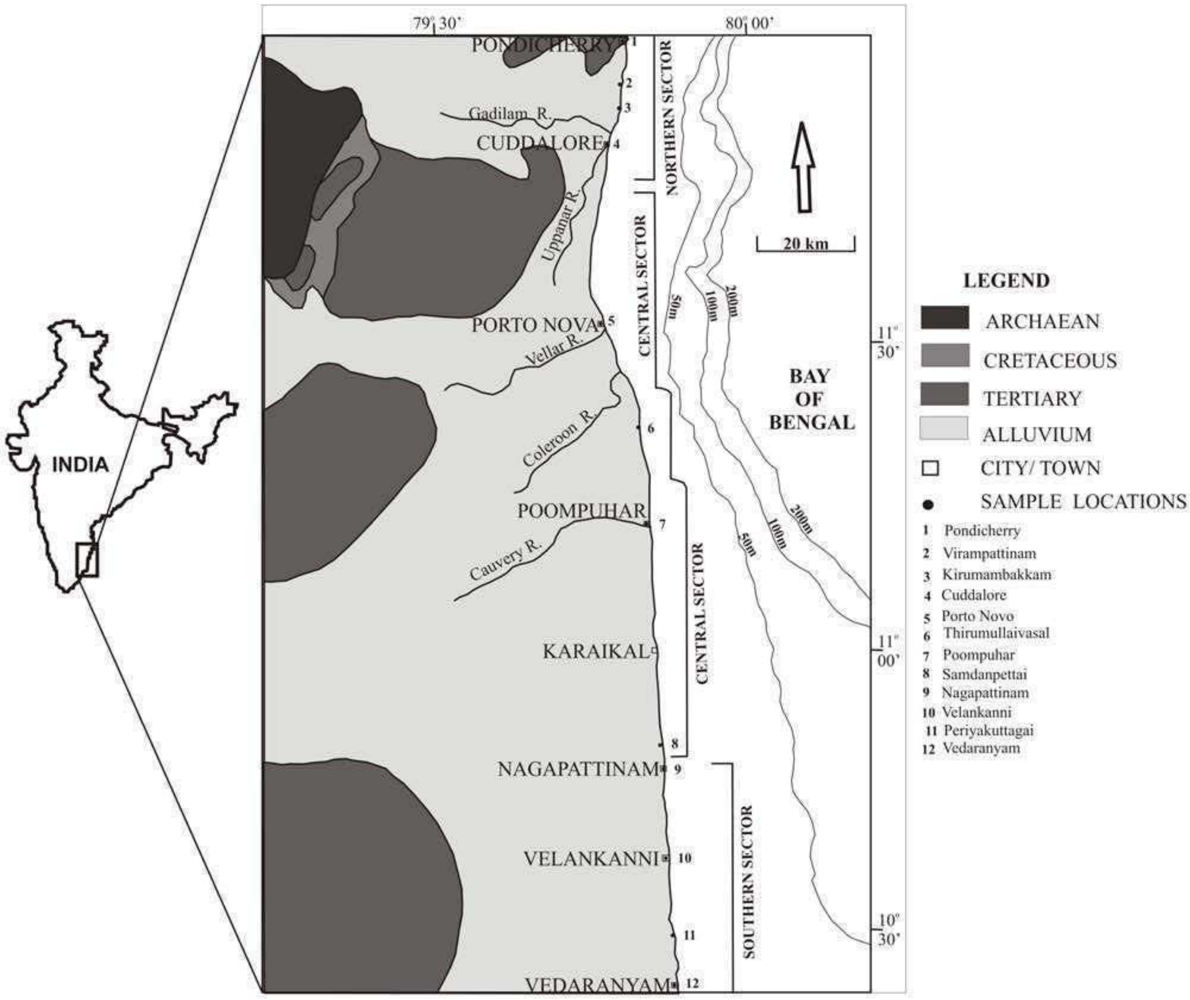

Fig.1. Location of study area, drainage, nearshore bathymetry and general geology of hinterland.

drainage pattern and geomorphology, the study area has been divided into three sectors viz. North (Stations 1 - 4), Central (stations 5-8) and South (stations 9-12) (Table 1).

In the Northern sector between Pondichery and Cuddalore, the beaches are marked by cliffs of 2.5-3 m height due to the erosion of foreshore by waves under high energy conditions. The width of the backshore is 30 m and fore-shore is 20-30 m. In the Central Sector, from Cuddalore to Nagapattinam, the entire foreshore and backshore is found to be carpeted by rich concentrations of black sands and garnets. In Karaikal, the backshore is wider for about 850 m (Table 1). The heavy mineral enriched zones are characterized by asymmetrical ripple marks in the backshore and dunes regions. This area is devoid of beach ridges. In the Southern sector from Nagapattinam to Vedaranyam the beaches are abutted by ridges of 1.5 - 3 m height. The beaches have abundant quartz and feldspars, are muddy and swampy and clay balls are noticed in the low tide region.

The Northern sector is characterized by high energy environment, due to wave convergence during southwest and northeast monsoons as well as during fair season (Angusamy et al. 2005). This high energy conditions are due to the presence of submarine canyons between Pondichery and Cuddalore (Vardhachari et al. 1968). The shelf in this area has a steep gradient and the coastline is dominated by wave cut cliffs and platforms.

The Central sector reflects mixed energy conditions. The region from Cuddalore to Portonovo shows a dominance of wave divergence and low energy whereas, south of Portonovo wave convergence and high energy conditions prevails during SW and NW monsoons and in fair weather period.

In the Southern sector partly wave divergence and low energy conditions prevails during NE monsoon and for rest of the period i.e. SW monsoon and fair season inept wave condition (normal condition) prevails (Angusamy et al. 2005).

Table 1. Classification of the study area into three sectors

	North (Stations 1 – 4)	Central (Stations 5 – 8)	South (Stations 9 -12)
Drainage	Uppanar, Gadilam	Vellar, Coleroon, Cauvery	Absent
Geomorphology	Beach Ridges - 2 to 3 series Cheniers - 2-3 series Beach Cliff - 2.5-3 m high	Selectively present Absent Absent	18 series Absent Absent
Beach Width	30-50 m	68-98 m, 850 m in the zones of enrichment of heavies	50-100 m
Beach Composition	Patches of heavy mineral enrichment	Heavy mineral rich	Clayey and siliceous
Coastal Configuration	N – S	N – S, NNW, SSE	N–S
Shelf Topography	Steeply slopping	Moderately slopping	Very gentle slopes
Sub Marine canyon	Present	Absent	Absent
Distance from shore line	20 m contour: 4.5 km 100 m contour : 10-12 km	8-10 km 18-21 km	20 - 34 km 40 -54 km
Current Velocity	1.8 - 3.6 (m/s)	1.5-1.8 (m/s)	0.01-0.08 (m/s)
Wave Height	1-1.5 m	0.75-1.25 m	0.3 m
During Cyclone	4-6 m	3-4 m	0.3-1.5 m
Geology	Mio – Pliocene Cretaceous deposits Quaternary sediments	Archaean Cretaceous deposits Quaternary sediments	Quaternary deposits

The wave heights range from 0.3 to 2.1 m and predominant average wave period is between 3 and 12 seconds. The estimated longshore sediment transport rate shows that the net transport rate along this coast is towards the north (at Poompuhar net transport is 146,000 m^3/year and gross transport is 478,800 m^3/year) (Sanilkumar et al. 2006).

MATERIALS AND METHODS

Four samples each from three sectors (totally 12 nos.) have been collected from the berm region of the backshore. Three size fractions viz. coarse, medium and fine were chosen from each sample and mono-crystalline quartz grains were picked-up to examine their surface features. The sand fractions were selected and treated chemically following the standard procedures (Krinsley and Doornkamp, 1973) to remove coating of iron oxide and organic matter. After thorough cleaning, the dried grains were placed in rows upon aluminium specimen stub coated with double sided scotch tape. The stubs were positioned in a rotating vacuum evaporator for coating by gold. Finally, the mounted grains were examined under a JOEL [JSM 5800] Scanning Electron Microscope and photomicrographs were taken.

RESULTS

The quartz grains of northern sector are predominantly of sub-rounded nature with conchoidal fracture which are small or large at times (Fig.2A). Conchoidal fractures are categorized as small, medium or large with class limits of 10 and 100 μm. These grains are marked by 'V' shaped indentations. The spatial distribution of the V's varies from grain to grain. The number and abundance of the V's are related to the duration and intensity of sub-aqueous impact and agitation. Impact V's are usually formed in high energy littoral environment. Linear groove plates occur as a series of linear grooves of different dimensions aligned at an angle to the grain surface (Fig.2B). Dish shaped depressions of varying sizes are also common (Fig.2C). Solution pits of varying size, shape are abundant. Circular and sub-circular types are common (Fig.2D). In many grains, precipitation features are ubiquitous in the form of globules, modifying the grain relief. In some grains, the edges are angular and at places silica precipitation is observed (Figs.2E and F).

In the Central sector, at station 5, the quartz grains are sub-rounded to rounded and show overcrowding of dish like features, impact marks, solution pits and impact V's of varying sizes and shapes (Fig.3A). It is common to see long crevasses traverse the grain surface. The areas

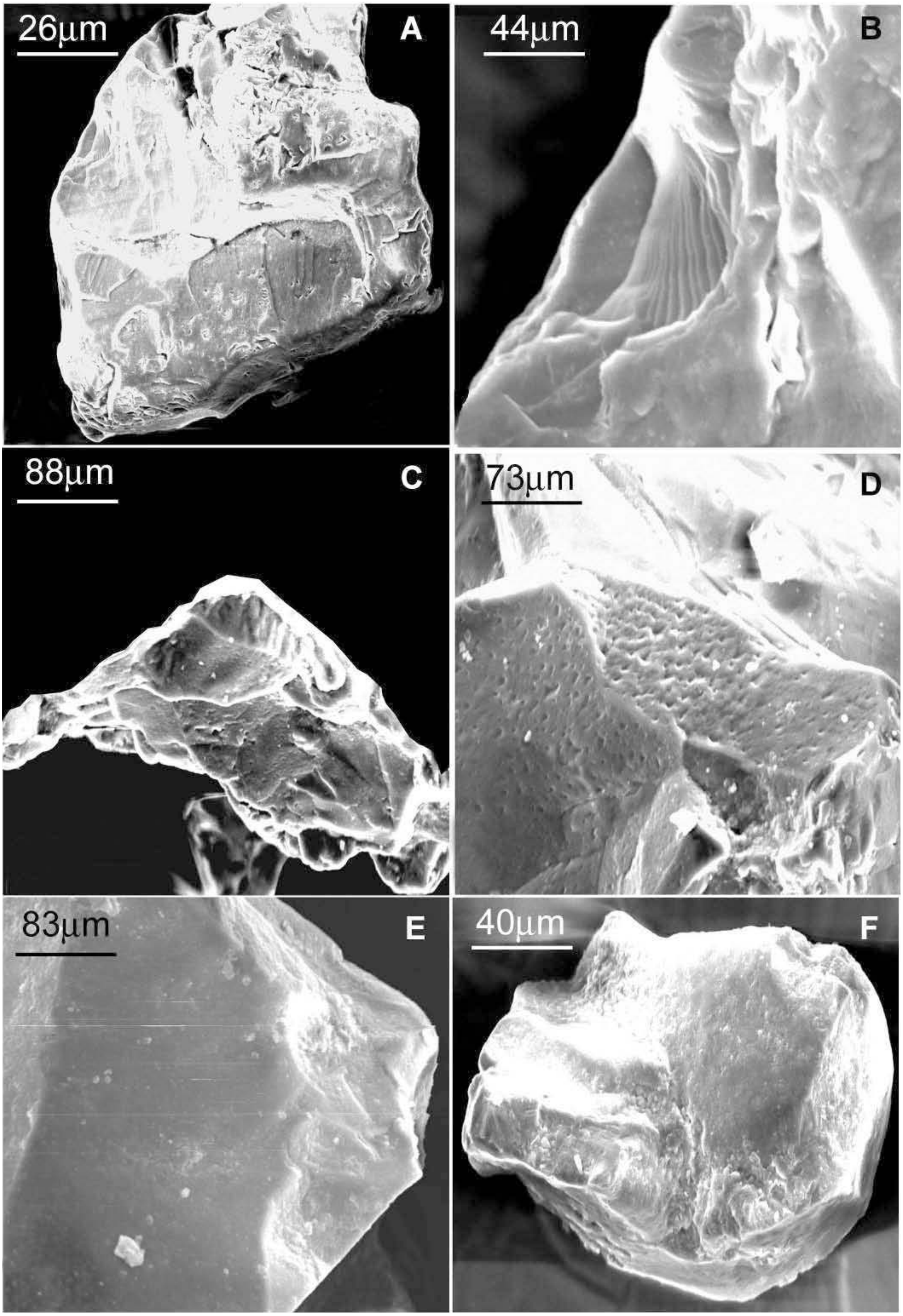

Fig.2. Scanning Electron Photomicrographs of quartz grains from Northern sector (A to F).

around the crevasses show impact features and solution precipitation, implying the role of intrastratal solutions (Fig.3B).

Quartz grains of station 6 are sub-rounded, showing impact V's on conchoidal breakage pattern, solution pits and removal of blocks of different sizes are also found (Fig.3A and B). Impact V's are oriented in different directions. Deep groves are oriented, irregularly, at an angle. In some grains, erosional concavities and silica precipitation are also noticed along the smoothened edges (Fig.3C) and as refilling of solution pits.

The quartz grains at station 7 in the Central sector show conchoidal fractured surfaces (Fig.3D) and dish like features arranged in a stepped fashion. Step like features are well defined, regular, parallel units and are quite common on grain surfaces. The steps are curved due to irregular breaking of the grains. In the long depressions caused by chemical etching, silica re-precipitation is found to fill the voids. Chemically etched spots are also found to be filled with silica precipitations. At station 8, grains are sub-rounded with more chemically etched features in the form of solution pits, suture marks, depressions and occasional silica precipitations (Fig.3E) than other high energy transportation features like concoidal fractures, impact V's etc.

In the Southern sector, at station 9, quartz grains with variable sizes of solution pits, chemically etched V marks and step like furrows and dish shaped depressions are very common (Fig.3F). Impact marks are of varying size and shape ranging from semi-circular to linear furrows or grooves and super imposed over concoidal fractured surfaces (Fig.3F). Large globules of precipitates are also common along the grain surfaces.

At station 10, grains are smoothened and sub-rounded. Linear grooves are common along the edges. Impact V's are abundant throughout the grain surfaces along with concoidal fractured surface (Fig.4A). In the enlarged views, dish like features are common and the grain surface is marked with solution pits and impact V marks. The solution pits are arranged in zig-zag fashion along the weaker plane of quartz grain (Fig.4B). At stations 11 and 12, etched 'V' marks are common (Fig. 4 C). The degree of etching varies according to the residence time. Quartz grains, showing rounded dish like depressions and strongly etched surfaces are also common (Fig.4D).

DISCUSSION

Profound differences are observed in the mechanical and chemical features of quartz grains from sector to sector. Though the features of chemical origin are common to all three sectors, actual difference in the geochemical environment i.e. type of chemical processes and their degree of activity in each sector is not exactly known as there is no specific detailed work available for reference from this region.

The Northern sector samples are characterised by abundant angular grains with conchoidal features and ' V' marks, indicating the prevalence of high energy environment (Krinsley and Donahue, 1968). The blocky conchoidal fractures are developed due to intense transportation in high energy surf zone (Krinsley and Donahue, 1968). The prevalence of high energy in the northern sector is supplemented by the steep gradient of the nearshore bathymetry as a result of submarine canyons, high energy wave conditions, erosive beaches and beach cliffs of 2.5-3.0 m height. 'V's are formed as a result of grain to grain collision (Manickam and Barbaroux, 1987). The abundance and size of the V's tend to increase when grains are subjected to longer period and higher intensities of sub-aqueous agitation (Manickam and Barbaroux, 1987). In the present study, the size of V marks varies between wide limits in the northern sector. Linear grooves, dish shaped features are also found to be common in the northern sector. Linear grooves and dish shaped depressions are usually formed by aeolian transport (Margolis and Krinsley, 1974), by collisions during formation of dunes. Littoral zone in the northern sector is adjoined by dune complexes as well as by two series of beach ridges. The quartz grains lifted from these landforms by aeolian processes must have mixed with the beach sediments. Quartz grains of northern sector also show features of silica precipitates and globules which must have been formed by the precipitation of silica from the chemical solutions, due to longer residence of the sediments in the depositional basin. The source of colourless garnet rich sediments of this area is attributed to Tertiary sediments (Angusamy et al. 2005). The influence of paleo- sediments in supplying the colourless garnets is corroborated by etched, pitted, grooved surfaces of the garnets (Angusamy et al. 2005). The presence of solution pits and re-precipitation in the pits in the quartz grains, supplements the prevalence of chemical processes, as well as the probability of their derivation from paleo-sediments of Cretaceous-Tertiary formations, in addition to the dominant mechanical processes in the Northern sector.

In the central sector, the quartz grains betray chemically etched pits, grooved surfaces, sub-rounded nature, precipitated silica globules, indicating the dominance of the local chemical processes. The increased rate of evaporation and the abundance of salts in the pore

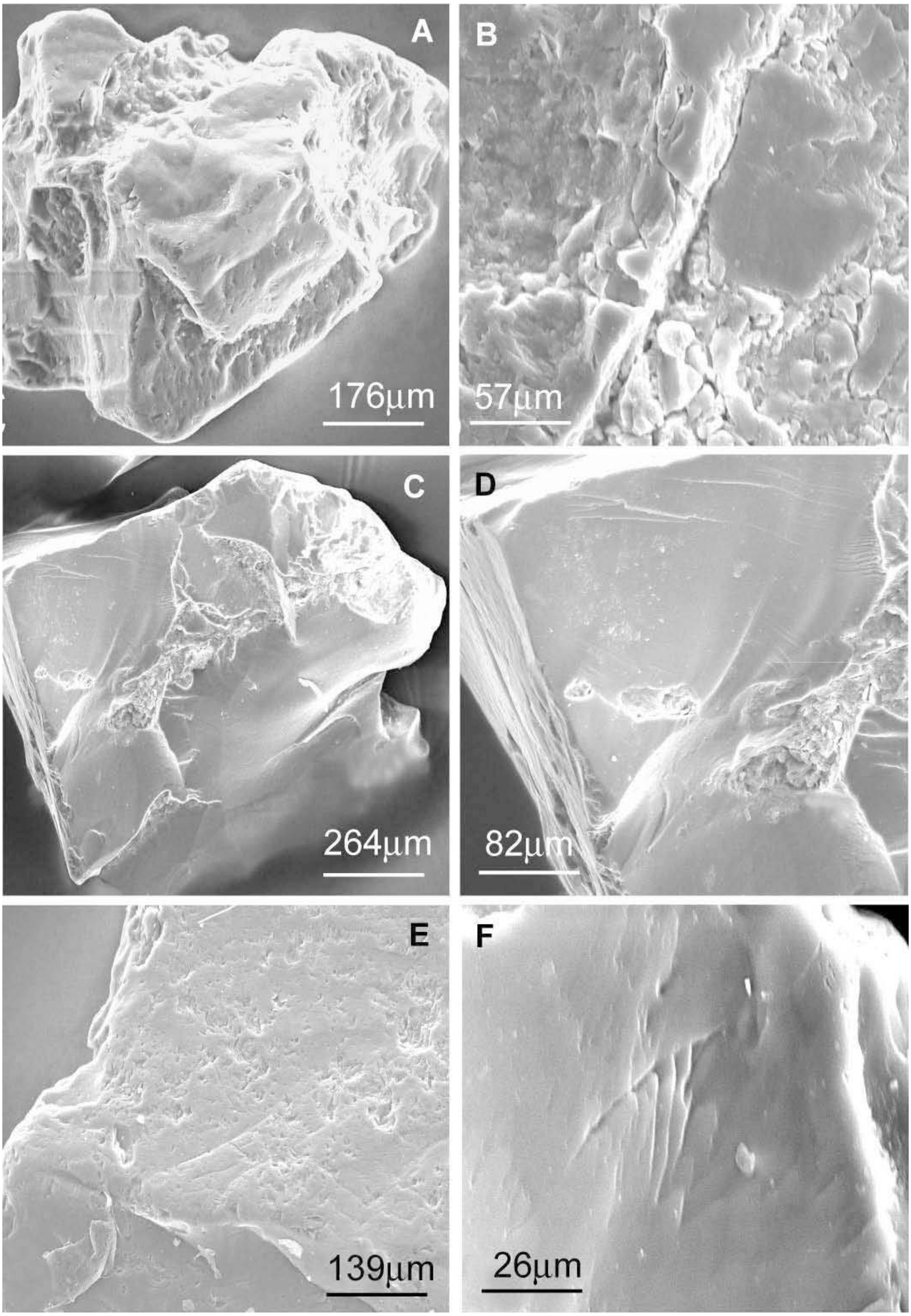

Fig.3. Scanning Electron Photomicrographs of quartz grains from Central sector (A to E) and Southern sector (F).

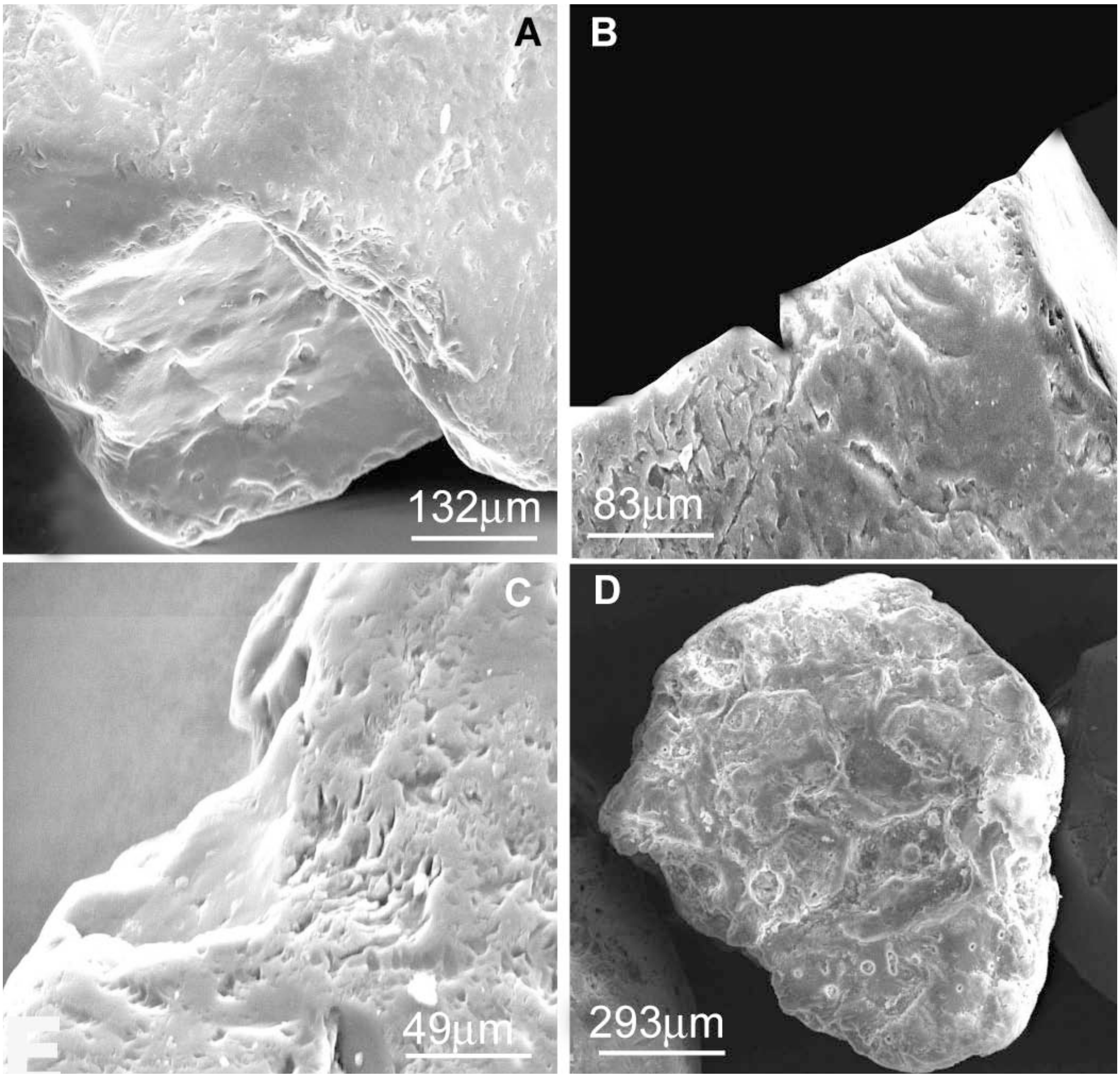

Fig.4. Scanning Electron Photomicrographs of quartz grains from Southern sector (A to D)

water, which increases the pH, are the important factors influencing the derivation of chemical features. The observed relative abundance of oriented 'V' marks suggests the collision of grains in the sub-aqueous high energy environment. Angular to sub-angular quartz grains of freshly derived nature with conchoidal fracture, with little 'V' marks but with solution pits and precipitated features, indicates again the influence of both chemical and mechanical processes. Though central sector is drained by number of rivers, the quartz grains of stations 5 and 6, hardly register the surface textures of low energy fluvial environment like bifurcating ridges, straight and linear steps which are reported in Yamuna river sediments (Tiwari et al. 2004), indicating the negligible influence of these rivers (Vellar and Coleroon) in depositing the sediments along the beaches. This is also supplemented by heavy mineral studies of the rivers of this region. These rivers contribute negligible amount of heavy minerals to the respective beaches (Angusamy et al. 2005; Mohan, 1995; Udayaganesan et al. 1998).

In the southern sector, the well rounded quartz grains are devoid of conchoidal fracture, indicating the prevailing wave shadow conditions or low energy wave conditions. The quartz grains typically bear the signatures of chemical etching by way of circular, semi-circular pits, irregular zig-zag etching patterns, etched 'V' marks. Unlike the other two sectors, the impact 'V's are rare. Step like furrow feature is also common (Mallik, 1992; Cater, 1984). These step like features are developed by grain fracturing during low energy fluvial transport followed by sub-aqueous collision (Mallik, 1992; Cater, 1984). The absence of drainage system in this sector indicates that the grains must have been transported from down south, by northerly moving littoral currents (Sanilkumar et al. 2006). The abundance of flaky heavy minerals in the southern sector has been suggestive of low energy depositional condition and their transportation by littoral currents (Angusamy et al. 2005). Besides, this region experiences lagoonal conditions as wave shadow regime prevails in this sector throughout the year. The maximum wave height in Vedaranyam region is 0.4 m during southeast monsoon and littoral transportation rate is $16\text{-}21 \times 10^3 m^3$ (Jena, 1997). Hence, the furrow like features must have been formed in a low energy sub-aqueous environment under fluvial conditions and later transported by littoral currents to this 'sediment sink'.

CONCLUSION

The present study has revealed that quartz grains of northern sector show the dominance of mechanical features like conchoidal fractures, impact V's etc. and less dominance of chemical features like silica globules and other precipitated features. However, the influence of aeolian processes in the deposition of quartz grains is also evidenced by the presence of mechanical features like linear grooves plates and dish shaped depressions.

In the central sector, quartz grains of sub-rounded nature depict etched pits, grooved surfaces and precipitated silica globules, indicating the dominance of chemical processes. Only at Cauvery River mouth, the grains show surface features characteristic of fluvial environment whereas in other stations non-fluvial surface textures dominate, indicating the lesser influence of fluvial domain in the study region.

In the southern sector, micro-textures of quartz grains register the signature of chemical processes by better rounding of the grains, solution pits and etched suture patterns arranged in a zig-zag manner. These features typify near surface digenetic environment. In addition, the presence of step like furrow structures, formed in the low energy fluvial environment, evidences the role of northerly moving littoral drift in transporting the quartz grains from a fluvial source.

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