Light minerals of beach sediments from Southern Tamilnadu, south east coast of India

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Anil Cherian[1,*]
Nayanarpandian Chandrasekar[1]
Victor Rajamanickam[2]

[1] Department of Coastal Mining,
Centre for Marine Science and Technology,
M.S. University, Rajakkamangalam, Nagercoil, 629 502 Tamilnadu, India;

e-mail: anilqq@rediffmail.com

[2] Department of Disaster Management,
School of Civil Engineering,
SASTRA Deemed University, Thanjavur, 613 403 Tamilnadu, India

*present address:
National Dewatering and Drainage Services Company,
Dubai, United Arab Emirtaes

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Abstract

A brief investigation of light minerals along the beaches between Valinokkam and Tuticorin has been carried out for the first time along the Southern Tamilnadu coast in order to discover the provenance of the sediments. The study spotlights a wide variation in light mineralogy along the three zones of the investigated area (Valinokkam, Vaippar and Tuticorin). A higher percentage of quartz is reported from the Valinokkam (48.34 to 68.63%) and Tuticorin zones (55.66 to 73.05%) than from the Vaippar zone (40.24 to 60.77%). The trend with regard to the maturity index is similar, with appreciably higher values in Valinokkam (1.15 to 1.89) and Tuticorin (1.61 to 1.94) than Vaippar (0.79 to 1.39). Morphological analysis of quartz grains shows a higher order of sphericity and roundness values in Valinokkam and Tuticorin as compared to Vaippar. Moreover, the surface texture

The complete text of the paper is available at http://www.iopan.gda.pl/oceanologia/

of quartz grains observed with the aid of scanning electron microscope (SEM) photographs reveals the presence of different depositional environments and the multiple origin of beach sediments in the study area. From the present study of the light mineralogy of beach sediments, it is inferred that the source of the sediments is a mixed type: igneous and metamorphic crystalline rocks, together with palaeosediments.

1. Introduction

The distribution and morphological properties of light minerals have persuaded many geoscientists to study them with respect to depositional environment and provenance. Earlier workers like Dake (1921), Wadell (1935), Rittenhouse (1943), Powers (1953) and Curray & Griffiths (1955) attempted the application of light minerals in provenance studies. Blatt & Christie (1963) used the character of undulatory extinction in quartz to differentiate igneous from metamorphic rocks. Ernst & Blatt (1964) analysed the properties of quartz from a sedimentary source to infer its provenance. Blatt (1967, 1982) used properties of quartz grains such as stability and roundness in order to understand provenance.

Van der Plas (1968) brought out the changes in the composition of different feldspars according to the type of parent rock. Basu et al. (1975) classified different types of undulatory extinction quartz to delineate the provenance. Pettijohn (1984) explained light minerals and their relation to sphericity, roundness etc., and attempted to assign these characters to the depositional environment. Anirudhan & Thrivikramaji (1991) illustrated the petrography of light detrital minerals of Bharathapuzha to decipher the depositional history. Muthukrishnan (1993) studied light minerals from the Gadilam river in order to understand the maturity of quartz, orthoclase and microcline. Udayaganesan (1993) and Rajamanickam & Muthukrishnan (1996) studied light minerals from Vaippar and Gadilam river sediments and concluded that they are influenced by the continental block provenances. Madhavaraju & Ramasamy (1999) explained the microtextures of quartz grains from the Ariyalur group of Thiruchirapalli Cretaceous formations for deciphering the depositional environment. Even though a number of studies on heavy mineral placers has been carried out along the study area, no systematic investigation has yet been initiated to gain an understanding of the light mineralogy of beach sediments and its relationship with provenance. The aim of the present paper is thus to decipher the provenance of beach sediments through the application of light mineral analysis along the study area.

The investigated area is located in the coastal tract of southern Tamilnadu. The coastal stretch between Valinokkam and Tuticorin extends over a distance of about 80 km. Covering the districts of Ramanathapuram and Tuticorin, the area is located between 8°45′ to 9°8′N and 78°10′ to 78°35′E (Fig. 1). The investigated area is chiefly underlain by Precambrian gneisses, charnockites and granites besides Quaternary sediments. Geomorphologically, the coastal stretch can be classified as a shoreline of emergence as identified from the beach ridges scattered along the study area (Loveson 1994, Chandrasekar et al. 2000). The drainage pattern of the area is mainly controlled and influenced by the presence of perennial rivers like the Gundar and Vaippar.

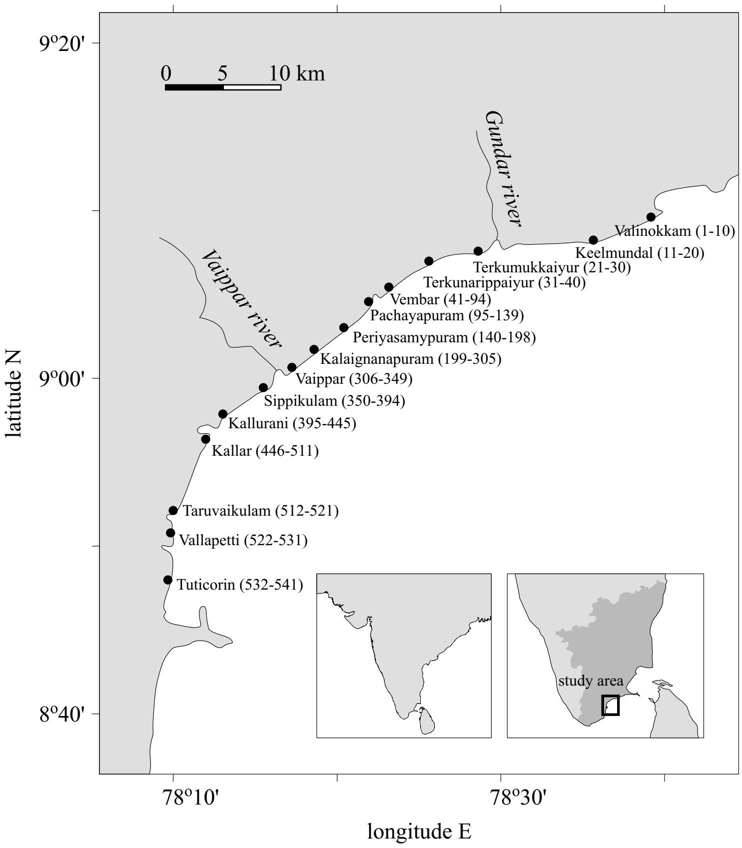


Fig. 1. Location map of the study area

2. Materials and methods

The samples were collected using an auger of 2 m length along the low-tide, mid-tide, high-tide and berm regions of the study area during November 2000, and then sifted on a Ro-Tap mechanical sieve shaker using

ASTM sieves at intervals of $\frac{1}{4}$ phi following preliminary chemical treatment. The sieved materials were collected separately and weighed. The sediment fractions were tabulated and retained for further studies.

Fraction-wise separation of light minerals was carried out by following the procedure described by Milner (1962). The light and heavy minerals were separated, with the use of bromoform (sp. gr. 2.89) then washed with acetone and again with distilled water. The washed fractions were dried under a hot air oven (60°C) until complete moisture removal. Subsequently, the dried fractions were weighed and the values tabulated. Since the study area has a potential for heavy minerals, the samples for the present analysis were chosen from different locations in such a way as to obtain the maximum concentration of light minerals. After sieving the maximum amount of sediment found in the +80, +120, +170, and +230 sieve fractions, a portion was taken for the preparation of slides and mineralogical study. In order to obtain the individual mineral percentage, mineral counting was performed by following the method of line counting (Galehouse 1969). The different mineral counts were then converted into percentages and the values tabulated.

3. Results and Discussion

3.1. Distribution of light minerals

Representative detrital mounts of the light fractions of +80, +120, +170 and +230 were selected for estimating the percentage distribution of these minerals. The average percentage count of different light minerals of three zones is presented in Table 1.

In the Valinokkam zone, the average percentage of quartz ranges from 48.34 to 68.63%. The dominance of monocrystalline quartz over polycrystalline quartz is noteworthy. Non-undulose monocrystalline quartz is found to be depleted compared to undulose quartz. The percentage of orthoclase and plagioclase is more or less uniform in this zone. However, untwinned orthoclase prevails over the twinned form. The lithic fragment ranges from 8.37 to 29.32%.

In the Vaippar zone, the average percentage of quartz lies between 40.24 and 60.77%, the monocrystalline type being dominant. The distribution of orthoclase is more or less the same as that in Valinokkam. In this latter zone there is an abrupt increase in rock fragments from an average of 15.35% to 34.12%. The plagioclase distribution ranges from 0.89 to 4.39%. The total percentage of quartz decreases in this zone, but in the Tuticorin zone, the average quartz percentage increases from 55.66 to 73.05%. All other minerals exhibit a distribution identical with that in Valinokkam. The

Table 1. Data on count percentage of different light minerals along the study area

Valinokkam zone / Minerals	Valinokkam (2)			Keelmundal (12)		
	Minimum	Maximum	Average	Minimum	Maximum	Average
Quartz	48.34	58.79	53.39	49.40	65.16	55.15
Monocrystalline	46.95	56.41	51.49	48.21	63.04	53.56
Undulose	35.66	42.67	40.51	40.03	48.23	42.77
Non-undulose	11.29	13.74	10.99	8.18	14.81	10.79
Polycrystalline	1.39	2.38	1.89	1.19	2.12	1.60
Orthoclase	21.90	23.65	22.58	23.12	24.28	23.49
Untwinned	18.96	20.81	19.99	21.23	21.39	20.90
Twinned	2.94	2.84	2.59	1.89	2.89	2.59
Plagioclase	0.00	0.23	0.09	0.18	0.94	0.44
Rock Fragments	17.44	29.32	23.87	11.38	26.06	20.92
	Keelmundal (14)			Terkumukkaiyur (21)		
	Minimum	Maximum	Average	Minimum	Maximum	Average
Quartz	58.97	64.12	61.93	70.19	62.57	65.46
Monocrystalline	57.08	62.23	59.72	66.35	59.61	62.01
Undulose	49.2	53.11	51.38	56.12	50.38	52.44
Non-undulose	7.88	9.12	8.34	10.23	9.23	9.58
Polycrystalline	1.89	1.89	2.21	3.84	2.96	3.45
Orthoclase	21.03	25.08	23.09	17.27	21.32	19.68
Untwinned	18.91	23.12	20.57	16.43	20.34	18.77
Twinned	2.12	1.96	2.52	0.84	0.98	0.91
Plagioclase	0.22	0.86	0.46	0.12	0.43	0.27
Rock Fragments	10.37	18.18	14.52	8.37	19.63	14.59

Table 1. (*continued*)

	Terkumukkaiyur (23)			Terkunarippaiyur (31)		
Minerals	Minimum	Maximum	Average	Minimum	Maximum	Average
Quartz	70.63	58.86	64.74	57.24	63.77	60.12
Monocrystalline	67.43	56.97	62.33	55.20	61.28	58.91
Undulose	60.31	51.11	55.15	41.08	45.33	43.85
Non-undulose	7.12	5.86	7.18	14.12	15.95	15.06
Polycrystalline	3.2	1.89	2.41	2.04	2.49	2.38
Orthoclase	18.64	21.33	19.91	20.07	22.41	21.09
Untwinned	16.84	19.2	17.91	18.64	20.93	19.30
Twinned	1.80	2.13	2.00	1.43	1.48	1.79
Plagioclase	0.23	0.46	0.33	0.13	0.32	0.22
Rock Fragments	8.38	22.27	15.02	14.59	22.56	17.41

Vaippar zone	Vembar (67)			Pachayapuram (112)		
Minerals	Minimum	Maximum	Average	Minimum	Maximum	Average
Quartz	44.00	53.71	48.33	42.33	46.15	44.05
Monocrystalline	43.16	51.23	46.85	41.37	45.26	43.01
Undulose	36.84	40.22	38.31	32.17	36.58	34.74
Non-undulose	6.32	11.01	8.53	9.20	8.68	8.27
Polycrystalline	0.84	2.48	1.48	0.96	0.89	1.04
Orthoclase	24.18	27.16	25.27	20.72	23.56	21.78
Untwinned	23.19	26.18	24.26	19.88	23.18	21.29
Twinned	0.99	0.98	1.01	0.84	0.38	0.49
Plagioclase	0.89	1.41	1.13	1.29	2.34	1.86
Rock Fragments	20.65	29.83	25.28	30.16	34.12	32.32

Table 1. (*continued*)

	Periyasamypuram (152)			Kalaignanapuram (202)		
Minerals	Minimum	Maximum	Average	Minimum	Maximum	Average
Quartz	40.24	50.27	46.75	45.42	50.68	48.75
Monocrystalline	39.21	49.46	45.75	44.29	49.84	47.79
Undulose	34.65	42.18	39.35	38.64	42.66	41.62
Non-undulose	4.55	7.28	6.40	5.65	7.18	6.17
Polycrystalline	1.03	0.81	1.00	1.13	0.84	0.96
Orthoclase	20.84	24.91	22.72	23.12	28.19	25.80
Untwinned	20.84	24.81	22.61	23.12	28.19	25.73
Twinned	0.00	0.10	0.11	0.00	0.00	0.07
Plagioclase	1.82	3.96	2.59	3.18	4.39	3.77
Rock Fragments	25.09	26.90	27.95	16.74	24.57	21.68
	Sippikulam (382)			Kallar (447)		
	Minimum	Maximum	Average	Minimum	Maximum	Average
Quartz	52.21	57.78	54.64	56.46	60.77	58.29
Monocrystalline	50.29	56.39	53.25	55.18	58.93	56.64
Undulose	43.29	48.36	45.13	48.69	52.47	50.30
Non-undulose	7.00	8.03	8.12	6.49	6.46	6.34
Polycrystalline	1.92	1.39	1.39	1.28	1.84	1.61
Orthoclase	22.12	24.48	23.41	18.12	20.31	19.29
Untwinned	21.84	24.38	23.28	18.12	20.31	19.25
Twinned	0.28	0.10	0.13	0.00	0.00	0.05
Plagioclase	1.29	2.30	1.90	0.84	1.20	1.00
Mica	0.00	0.45	0.13	0.00	0.00	0.00
Rock Fragments	15.35	23.10	20.06	17.89	23.34	21.47

Table 1. (*continued*)

Tuticorin zone / Minerals	Taruvaikulam (512)			Taruvaikulam (520)		
	Minimum	Maximum	Average	Minimum	Maximum	Average
Quartz	62.42	73.05	65.99	55.66	68.83	61.66
Monocrystalline	60.23	70.21	63.43	53.62	65.65	59.09
Undulose	51.27	53.22	50.09	51.23	61.81	54.99
Non-undulose	8.96	16.99	13.34	2.39	3.84	4.09
Polycrystalline	2.19	2.84	2.56	2.04	3.18	2.58
Orthoclase	18.00	22.53	20.07	16.81	21.61	19.63
Untwinned	16.92	21.32	18.99	15.61	20.38	18.33
Twinned	1.08	1.21	1.08	1.20	1.23	1.30
Plagioclase	0.00	0.43	0.25	0.10	0.46	0.22
Rock Fragments	8.95	18.03	13.70	11.56	27.43	18.49
	Vallapetti (523)			Tuticorin (539)		
	Minimum	Maximum	Average	Minimum	Maximum	Average
Quartz	58.97	64.12	61.93	58.86	70.63	64.74
Monocrystalline	57.08	62.23	59.72	56.97	67.43	62.33
Undulose	49.2	53.11	51.38	51.11	60.31	55.15
Non-undulose	7.88	9.12	8.34	5.86	7.12	7.18
Polycrystalline	1.89	1.89	2.22	1.89	3.2	2.41
Orthoclase	21.03	25.08	23.10	18.64	21.33	19.92
Untwinned	18.91	23.12	20.57	16.84	19.2	17.92
Twinned	2.12	1.96	2.53	1.8	2.13	2.00
Plagioclase	0.22	0.86	0.46	0.23	0.46	0.33
Mica	0.00	0.42	0.15	0.00	0.34	0.10
Rock Fragments	10.2	18.18	14.51	8.38	22.2	15.01

absence of microcline in the beach sediments is probably due to the low resistance of this mineral to weathering.

The higher percentage of microcrystalline quartz is characteristic of all three zones. The reduced percentage of polycrystalline quartz is probably due to dilution by a fresh supply of monocrystalline quartz. Moreover, polycrystalline quartz grains are expected to disintegrate during the course of transportation from the source. Blatt & Christie (1963) articulated a similar view. This may be a credible reason for the low percentage of polycrystalline quartz in the beach sediments of the study area. The higher percentage of lithic rock fragments can be assumed to be a contribution from external agents other than riverine donation, such as onshore-offshore migration.

The maturity index of light minerals along the three zones of the study area is presented in Table 2. In Valinokkam and Tuticorin, the maturity index is higher, ranging from 1.15 to 1.89 in the former zone and from 1.20

Table 2. Composition maturity index of representative samples from the three zones of the study area

Valinokkam zone		
Sl No.	Sample No.	MI
1	2	1.15
2	12	1.23
3	14	1.63
4	21	1.89
5	23	1.84
6	31	1.55
Vaippar zone		
Sl No.	Sample No.	MI
7	67	0.94
8	112	0.79
9	152	0.88
10	202	0.95
11	382	1.20
12	416	1.39
Tuticorin zone		
Sl No.	Sample No.	MI
13	520	1.94
14	527	1.61
15	534	1.63
16	539	1.84

Note: Sl No. – serial number; MI – maturity index.

to 1.94 in the latter. The maturity index in Vaippar zone lies between 0.79 and 1.39. The higher order of the maturity index in Valinokkam and Tuticorin betrays the presence of beach sediments. The lower maturity index in Vaippar is indicative of a supply of river sediments from adjacent rivers along the study area. Moreover, the maturity index of river sediments generally shows a significant decrease when compared to beach sediments. A similar observation was made by Rajamanickam & Muthukrishnan (1996) with respect to Gadilam river basin sediments, Tamilnadu.

The higher percentage of undulose quartz along the study area suggests a major contribution from metamorphic rocks. The presence of non-undulose quartz indicates that a significant supply has been derived from acidic igneous rocks. The noteworthy presence of polycrystalline quartz, feldspar and rock fragments suggest that recent sediments have not had much influence on this environment. The extremely high percentage of rock fragments along the Vaippar zone can be assumed to be a contribution from outside agents other than fluvial sources. The higher percentage of untwinned orthoclase is supported by the supply from plutonic igneous rocks pooled with metamorphic rocks.

3.2. Quartz morphology

Among the light minerals under investigation, quartz is appreciably stable and the sediments containing feldspars are almost entirely decomposed. An attempt has therefore been made to understand the morphology of quartz grains, especially the roundness and sphericity parameters. Many authors have propounded different methods for studying the morphology of quartz: those adopted by Rittenhouse (1943), Powers (1953) and Lindholm (1987) are convenient and take up little time.

3.3. Roundness

Roundness is an entirely different factor when compared to the sphericity, shape and size of sediments. It can be defined as the relationship between the sharpness of the edges and corners (Wentworth 1919). Roundness describes the degree of abrasion of clastic fragments and provides evidence of time or distance of transport. Since light mineral fractions can decipher the grain morphology, different detritally mounted slides have been used to evaluate the roundness of quartz grains. Keeping the time factor in mind, the visual observation method has been adopted using the comparison charts of Powers (1953) for roundness studies. In order to attain a better accuracy, about 300 individual grains in each fraction of samples selected from the three zones (+80, +120, +170 and +230) were studied. Table 3 presents the

Table 3. Roundness analysis of representative quartz from the three zones of the study area

	Valinokkam zone								
Sample No.:	2			12			21		
Range	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
0–0.17	1.26	2.11	1.68	1.36	2.59	1.92	1.26	3.66	2.21
0.17–0.25	1.29	3.22	2.65	1.59	3.59	2.47	3.26	6.55	4.90
0.25–0.35	9.58	13.66	11.80	10.48	15.89	12.83	5.98	12.36	9.80
0.35–0.49	32.55	43.21	39.30	29.58	38.98	34.37	30.50	36.22	32.67
0.49–0.70	31.59	20.22	35.99	39.58	48.26	42.30	38.66	45.69	42.15
0.7–1.0	6.84	12.33	8.57	4.77	7.46	6.12	5.28	11.28	8.28
	Vaippar zone								
Sample No.:	31			67			202		
Range	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
0–0.17	1.26	3.21	2.21	2.36	4.12	3.32	1.39	3.14	2.37
0.17–0.25	3.69	6.58	5.21	7.84	12.97	9.55	8.46	12.16	10.56
0.25–0.35	10.36	15.66	12.20	45.39	56.34	49.99	48.46	56.18	52.48
0.35–0.49	31.08	36.99	33.33	30.12	36.12	32.36	27.84	33.20	30.32
0.49–0.70	35.48	42.69	40.12	0.01	7.30	3.64	0.27	12.54	4.28
0.7–1.0	2.98	9.48	6.93	0.00	4.09	1.13	0.00	1.03	0.40
	284			382			416		
	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
0–0.17	0.96	2.13	1.44	0.83	2.43	1.82	0.49	2.12	1.30
0.17–0.25	9.24	11.84	10.44	6.43	11.34	9.02	9.88	20.46	13.10
0.25–0.35	50.38	58.20	54.13	48.23	58.14	53.09	40.84	50.96	47.01
0.35–0.49	30.12	34.26	31.82	31.12	38.12	34.35	30.28	36.20	33.48
0.49–0.70	0.02	4.97	1.81	0.02	6.23	1.51	1.25	6.23	5.02
0.7–1.0	0.00	1.01	0.36	0.00	0.00	0.00	0.20	1.02	0.43

Table 3. (*continued*)

Sample No.:	Tuticorin zone					
	523			539		
Range	Minimum	Maximum	Average	Minimum	Maximum	Average
0–0.17	0.84	1.23	1.02	1.23	2.92	2.21
0.17–0.25	8.12	8.92	8.40	6.23	8.12	6.82
0.25–0.35	0.28	4.13	1.73	0.21	7.24	4.47
0.35–0.49	29.69	38.12	32.49	38.95	43.20	41.55
0.49–0.70	50.86	60.23	56.33	40.28	48.12	44.95
0.7–1.0	0.00	0.12	0.03	0.00	0.40	0.25

value of the counts as a percentage. The percentage of a different group of grains with roundness values endorses the part played by multiple sources in view of the appreciable percentage of sub-angular, sub-rounded and rounded grains in the same fraction. The variations in the roundness percentage in the individual fractions indicate a similar trend within a sample. When an average of different samples is taken, the sub-rounded to rounded grade is dominant in the Valinokkam and Tuticorin zones, whereas the sub-angular grade is predominant in the Vaippar zone. This phenomenon indicates that the sediments in Valinokkam and Tuticorin are derived mainly from beach sediments that have evolved from palaeosediments, in addition to present-day riverine and marine sediments. The supremacy of angularity in the Vaippar zone clearly suggests that the sediments have been transported only a short distance and are deposited nearer to the source from nearby rivers along with marine sediments. This discrepancy can be attributed to the possibility that the beaches are the epicentre of different natural processes and hydrodynamic conditions; the reworked sediments in the beach must have been subjected to rigorous wear and tear by strong waves and currents and undergone further roundness.

3.4. Sphericity

According to Wadell (1935), sphericity is defined as the ratio of the surface area of a sphere of the same volume as the fragment in question to the actual surface area of the object. The sphericity values measured using the procedure of Rittenhouse (1943) is given in Table 4. The values show a clear distinction between zones, such that the Valinokkam zone exhibits 29.48% to 59.12% (sphericity factor 0.90) and 28.12% to 51.12% (sphericity factor 0.95) the corresponding figures for Tuticorin are 20.26 to 40.21% (sphericity factor 0.9) and 35.12 to 54.69% (sphericity factor 0.95). In the Vaippar zone, the percentage of sphericity ranges from 20.26 to 69.29% (sphericity factor 0.90) and 16.28 to 40.29% (sphericity factor 0.95). From the analysis one can conclude that the sediments in Valinokkam and Tuticorin display a higher order of sphericity, which implies the concentration of sediments from a palaeoenvironment along with present-day marine environments. In Vaippar, the drop in the sphericity factor suggests the addition of material from fluvial to marine environments.

3.5. Scanning electron microscope studies

The scanning electron microscope (SEM) is probably the most frequently used auxiliary instrument in light mineral studies for examining the surface textures of grains in detail, for mirroring the effects of sub-aerial or

Table 4. Sphericity analysis of representative quartz samples from three zones of the study area

	Valinokkam zone					
Sample No.:	2			12		
Mean sphericity	Minimum	Maximum	Average	Minimum	Maximum	Average
0.70	10.21	18.12	14.34	8.12	10.11	9.10
0.90	29.48	38.60	32.13	52.19	58.12	54.52
0.95	46.29	51.12	49.01	22.26	30.11	26.94
1.00	0.55	6.66	4.53	6.39	14.21	9.44
	21			31		
	Minimum	Maximum	Average	Minimum	Maximum	Average
0.70	10.63	16.11	12.42	7.26	11.12	9.32
0.90	49.20	57.10	52.19	54.17	59.12	56.18
0.95	28.12	38.11	33.14	26.12	30.11	28.25
1.00	0.56	3.66	2.25	3.49	9.29	6.26
	Vaippar zone					
Sample No:	67			202		
Mean spherity	Minimum	Maximum	Average	Minimum	Maximum	Average
0.70	12.89	18.12	15.245	8.39	12.38	10.96
0.90	40.13	50.2	43.2	52.18	58.96	55.185
0.95	31.28	40.29	36.5	24.38	28.12	25.9975
1.00	3.25	5.90	5.05	7.23	8.47	7.86

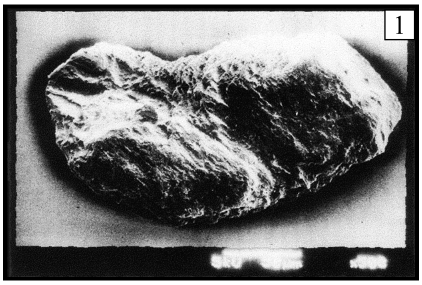
Table 4. (*continued*)

Sample No:	284			382		
Mean sphericity	Minimum	Maximum	Average	Minimum	Maximum	Average
0.70	6.39	8.96	7.71	6.28	7.29	6.90
0.90	60.29	70.31	66.99	58.15	69.29	62.94
0.95	16.28	26.12	20.22	16.29	20.12	18.87
1.00	0.43	8.10	5.08	4.31	15.72	11.29
	416					
	Minimum	Maximum	Average			
0.70	14.86	19.21	17.60			
0.90	38.31	46.19	41.98			
0.95	35.12	37.21	35.98			
1.00	0.46	8.28	4.44			
	Tuticorin zone					
Sample No:	523			539		
Mean spherity	Minimum	Maximum	Average	Minimum	Maximum	Average
0.70	16.81	27.96	25.9	7.88	11.96	9.63
0.90	20.26	31.28	26.645	33.69	40.21	36.68
0.95	35.12	49.12	39.6025	48.12	54.69	50.57
1.00	2.1	13.81	7.85	1.39	5.31	3.15

subsurface dissolution processes, and for aiding the assessment of post-depositional diagenetic modifications (Setlow & Karpovich 1972, Morton 1984). Krinsley & Doornkamp (1973), for example, used the surface textures of quartz grains in order to achieve an understanding of the post-depositional or diagenetic history of the sediments. During the process of transportation and deposition, various microfeatures are developed by mechanical and chemical processes and are influenced by physical and chemical properties of grains such as hardness, cleavage, solubility, tenacity, etc. The complete process is governed by the energy level and chemistry of the environment.

Commonly observed features include conchoidal fractures with cavities, and solution-pitting (Plates 1 and 2); sub-rounded quartz grains showing conchoidal fractures with V marks (Plate 3), chemical etch marks (Plate 4) and solution pits and silica precipitation patterns (Plate 5) are occasional features. High-energy conditions and the aquatic transport system can give rise to the observed cavities and conchoidal fractures, where grains are freshly liberated from the weathering of the crystalline source rock or under glacial conditions (Higgs 1979). In the present case, high-energy aquatic transport appears to be responsible for their formation along the quartz surfaces. Unoriented solution pits are developed from the chemical solution activity of seawater under alkaline conditions. The oriented crescent-shaped pits result from prolonged chemical activity and a longer residence time. Some of the grooves may also have resulted in this way, and the V-shaped impact pits will have originated from sub-aqueous impact and the agitation of water. Small fractures may have been caused in turbulent rivers. The chief agent for solution activity is seawater. Periods of intense evaporation regulate the water's alkalinity. In shallow coastal areas, photosynthesis takes place in marine sediments. Rapid evaporation of interstitial water in the exposed foreshore beach occurs during dry intervals. Therefore, the alkalinity gradient will be high, leading as a result to more intense etching of chemical microfractures, as reported from the Tobago coast (Mukherji et al. 1981). Besides seawater, rainwater and interstitial water affect the mineral surfaces as well. Thus, in the present investigation, the quartz grains of the beaches show both conchoidal fractures and etched marks, which are indicative of a high-energy environment as well as the longer residence time of sediments in the depositional basin (Anil Cherian 2003).

The quartz grains from the study area are in general sub-angular to rounded, with the presence of dominant mechanical signatures like cavities and conchoidal fractures. These features are probably formed during early transport or weathering and suggest a high-energy environment or longer fluvial transport towards the littoral zone. Moreover, the presence of



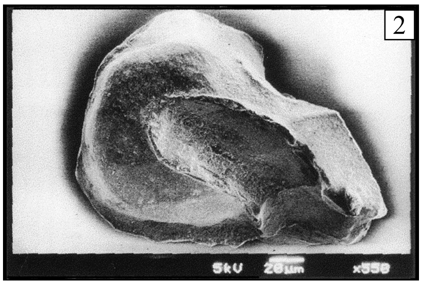


Plate 1 and Plate 2. Quartz grain showing conchoidal fracture with cavities and solution pitting

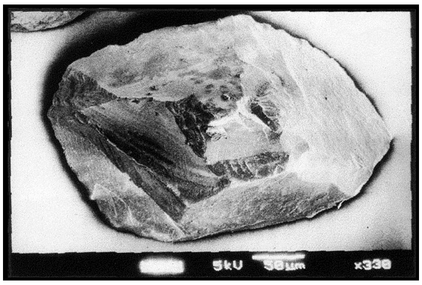


Plate 3. Subrounded quartz grains showing conchoidal fracture with V marks

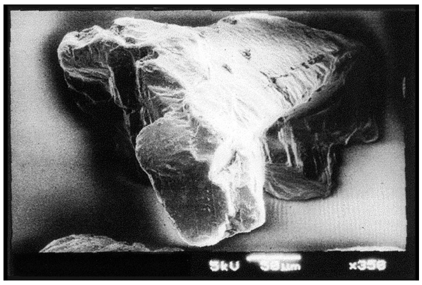


Plate 4. Quartz grain with chemical etch marks

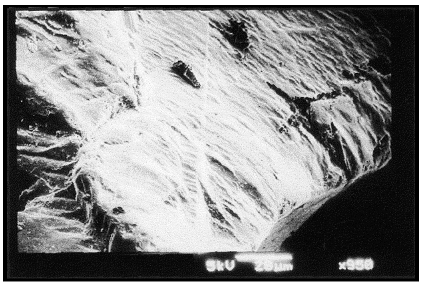


Plate 5. Quartz grain with solution pits and silica precipitation patterns

mechanical features like V-shaped pits and conchoidal fractures suggest that quartz is formed by grain to grain collision in an aquatic medium (Higgs 1979, Mallik 1986). The pitted appearance indicates post-depositional events. This kind of amalgamation of different features demonstrates that the sediments have undergone different processes, where each event has left its own signature on the grains. From the study of quartz grains, it is evident that these sediments are derived not from a single source but from both igneous and metamorphic crystalline rocks, and also palaeosediments, these too from a distant mixed source through the action of littoral currents.

The present investigation has clearly documented the disparity in light mineralogy from zone to zone. In the Valinokkam and Tuticorin zones, the percentage of quartz was found to be higher than in the Vaippar zone. The maturity index is appreciably higher in Valinokkam and Tuticorin than in Vaippar; this is attributable to the supply of sediments from multiple sources. In Valinokkam and Tuticorin, quartz grains are sub-rounded to rounded, whereas sub-angular grains are present in Vaippar. Sphericity values are higher in Valinokkam and Tuticorin as compared to Vaippar. The morphology of quartz grains has clearly discriminated different depositional environments along the study area. In the Valinokkam and Tuticorin zones, it is inferred that the major concentration of sediments is from reworking of sediments from offshore along with fluvial and marine sediments. The beaches in the Vaippar zone indicate the accumulation of larger amounts of fluvial sediments with palaeosediments. From a study of SEM photographs, the depositional environment can be categorized in terms of physical and chemical energy gradients. Moreover, the study of quartz grains has pointed to the source of sediments, i.e. both igneous and metamorphic crystalline rocks transported some considerable distance from a mixed source, in addition to palaeosediments, which littoral processes have carried to the beaches from a distant source.

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