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Physical characteristics and distribution of bottom sediments from the Kelantan River Delta towards the South China Sea continental shelf, Malaysia

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Abstract: The preponderance of sedimentological studies in the Kelantan River Delta onwards South China Sea shelf has led to a relatively good understanding on the sediments distribution and characteristics. The sediments of the area vary from very poorly sorted to very well sorted mixtures of sand, silt and clay and can be divided into three groups. Textural analysis of 65 surficial sediment samples showed that group 1 (silty) has a silt percentage of 65% to 85%, group 2 (silty sand) is dominated by sand ranging from 64% to 88% with the silt size varying between 12% to 23% and group 3 (sandy) is made up of 78% to 100% sand and 0% to 22% silt. Mineralogical analyses showed that the samples are dominated by polycrystalline sutured and straight boundary quartz as well as monocrystalline quartz. Small amounts of feldspar, mica and lithic fragments are present, while organic material is abundant. A semi-quantitative analysis of quartz grains surface texture and morphology was used to interpret the history of the grains. Six types of grains have been recognized; (a) irregular shape with various angles; (b) irregular surfaces with fractured plate and elongated fragments; (c) well rounded, with V marks, oriented etched pits on surface and protruding edges; (d) irregular breakage with rough texture on planar surface, adhering particles with uneven grooves and V marks with dimensions of <2µm; (e) irregular shape with rounded protruding edges, rough surface with oriented etched pits and V marks with dimensions of <2µm and adhering particles with trail of abrasion; and (f) very rough surface with irregular shape and protruding edges, abundant cracks and detachment of small particles and etching holes, V marks > 2µm dimension. In terms of distribution it can be divided into two sedimentological provinces according to the interrelationship between grain size, mineralogy, textural and morphology of sediment. Province A covers the shallower parts of the study area, which accumulated a large amount of silt and clay that possibly originated from the nearby land areas brought down by the Kelantan River and deposited as Recent sediments. Province B which covers most of the outer part of the shelf area, contains Recent and relict sediments with lesser amounts of inland sediment input. The relict sediments consist of oceanic sub-arkosic sand, which was deposited circa 5000 yr. BP during the mid Holocene relative sea-level low stand.

Keywords: Delta, sedimentology, provenance, Kelantan River, Peninsular Malaysia

INTRODUCTION

The textural characteristics of deltaic and shelfal bottom sediments provide a record of depositional history of basins, which can be related to tectonic history, provenance, changes in basin hydrodynamics and climate. Therefore, numerous works have recently been carried out by researchers to understand the characteristics, distribution pattern and size, mineralogical contents and micro characters of bottom sediments, using different approaches such as geophysical studies, sedimentological studies, sedimentation rate, geochemical studies, and hydrodynamic impact.

Sedimentological reconnaissance surveys of the study area were conducted by several previous workers including Zakaria (1972a, 1972b, 1975, 1980), and Kamal Roslan *et al.* (1997). The study area located at the Kelantan River Delta covers an area of approximately 1879 km^2 (3 km long and 8 km wide) (Figure 1). In this study, bottom samples were collected from Kuala Besar, Pantai Mek Mas and Pantai

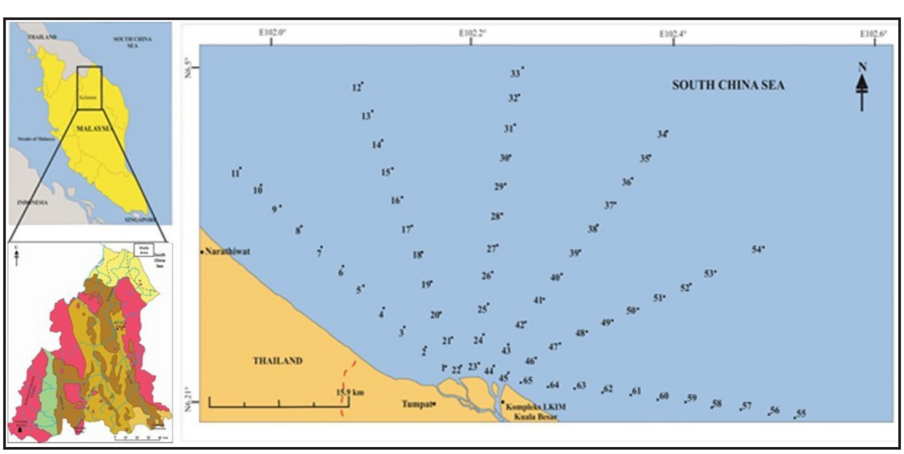

Figure 1: Study area and sampling locations.

Semut Api, outwards until the shelf area with the distance of sampling localities from the shoreline is about ~33 km. The purpose of this study is to determine the textural, mineralogical and morphological characteristics of bottom sediments in the Kelantan Delta and adjacent shelf and to map its distribution. Accordingly, the genetic sources and provinces of sediment distribution will be better discussed and interpreted.

GEOGRAPHY, CLIMATE SETTING AND OCEANOGRAPHY

The study area which is located in the northeastern part of Peninsular Malaysia receives its sediment supply from the Kelantan River, which is the largest river on the peninsula, and forms the Kelantan River delta. The area experiences an equatorial climate throughout the year and has a temperature range between 21°C to 35°C. The area is affected by two types of wind known as the southwest monsoon (from late May to September) and the northeast monsoon (from November to March). These prevailing monsoon seasons affected the speed and direction of the wind in the South China Sea region throughout year.

During the southwest monsoon the wind blows from the southwest at a speed of about 15 knots, while for the northeast monsoon season, the wind normally moves from the east or northeast at a speed of 10 to 20 knots and can sometimes reach speeds of up to 30 knots (Malaysia Meteorological Department, 2014).

Koopsman (1972) recorded that the Kelantan River Delta is influenced by a destructive wave type that caused erosion at the upper beach and deposition at the offshore bars during the northeast monsoon. The strong wave action during the monsoon changed the estuary and delta very quickly and causes the oblique movement of sand distribution from north to the northwest area of the delta. Waves hit the coast at an angle and tend to erode redistributed sediments along the beach and the sediments debouching from the Kelantan River (Kamal Roslan *et al.*, 1997).

REGIONAL AND GEOLOGICAL SETTING

Based on river drainage trend, the sources of sediments discharged from the Kelantan River come from hinterland areas which are marked by three mountains, i.e. Gunung Cintawasa (elevation 1185 m) in the southeast, Gunung Korbu (elevation 2183 m) in the south and Gunung Stong (elevation 1422 m) in the eastern region of Kelantan. These areas are drained by three main rivers known respectively as Sungai Lebir, Sungai Nenggiri and Sungai Galas which are part of the upper reaches of the Kelantan River.

According to Kamal Roslan *et al*. (1997), the Nenggiri River flows over granite and metamorphic rocks which contributed quartz and feldspar minerals, while the Lebir River and Galas River flow over argillite sedimentary rock, limestone and volcanic sandstone which supply sediments consisting of different grain sizes and mineral compositions. The intense weathering and erosion from various sources might also have influenced the distribution of sediments in the offshore areas.

PREVIOUS WORK

Little is known about the sediment provenance and distribution in the area starting from the shoreline of the Kelantan River Delta to the South China Sea shelf. With the exception of grab samples collected by Zakaria (1972a), Kamal Roslan *et al*. (1997) and Wang *et al*. (2017), no study was undertaken until now. According to the previous researches, the sediment dispersion of Kelantan River Delta affected by wind speed and climate change of monsoon (Dale, 1956; Zakaria, 1972a) directed the oblique movement of sand towards the northwest area of the delta (Koopsman, 1972). The dispersion of sand sized sediments are dominant in Kuala Besar area whilst the eastern part of the delta are dominated by finer sediments (Kamal Roslan *et al.,* 1997). Though a number of studies have been published on sedimentology, geography and landsat image in the area (Dale, 1956; Koopsman, 1972; Zakaria, 1972a; 1972b; 1975; 1980 and Kamal Roslan *et al*., 1997), no extensive sedimentological work has been conducted in the offshore areas. Apart from that, this research mainly accomplished the gap of sedimentological aspects in Kelantan River Delta by using the grab sample sediment distributed by the factors listed by the previous researchers, leads to a better understanding of the factors implication towards the sediment distribution in the basin.

METHODS

Field sampling

Field work was carried out in March and May 2014 using systematic sampling technique with ~3 km sampling interval using a boat. The water depth ranges from 1 meter to 33 meter and the depth were measured using portable depth meter instrument. A total of sixty-five surface bottom sediment samples were collected using a grab sampler, which covered an area of ~1386 km^2 that commenced from the shallow marine area in the delta front to about 30 km outwards the continental shelf of South China Sea.

Grain size analysis

Sixty-five sediment samples (see Table 1) from the study area were analyzed using coarse and medium fraction sieves, while the fine fractions were analyzed using the hydrometer technique as outlined by Folk (1968) using the standard micrometers scale. The results of size grain size analysis were presented in terms of mean, deviation, skewness and kurtosis, as proposed by Folk (1980).

Petrography

Forty-seven sand fractions (see Table 1) were selected for petrographic studies. To achieve this goal, thin sections of the loose sediments were produced using a standard thin section preparation method. The thin sections were then subjected to microscopic study to determine their mineral composition and texture.

Scanning electron microscopy of quartz

Samples from seven localities (see Table 1) were also selected for study using scanning electron microscope.

Table 1: Summary of test, sample number and description.

Test	Sample Number/Locality	Description
Grain size analysis	All samples (65 samples)	Represent the whole study area
Petrography	Fine, medium and coarse sand – sample number 4, 11, 26, 29, 31, 33, 55, 57, 58, 60 Fine sand fraction only – sample number 2, 6, 8, 23, 24, 25, 43, 45	Represent the whole study area
Scanning electron microscopy of quartz	Sample number 23, 24, 25, 26, 29, 31, 33	Represent the whole study area with the interval distance of selected samples range from ~200 meter

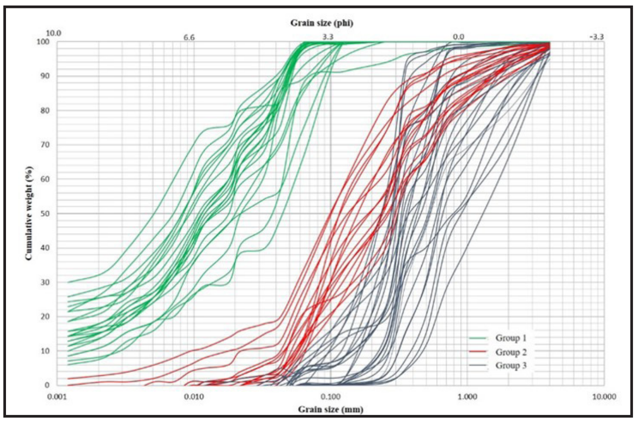

Figure 2: Cumulative curve showing the three groups of sediments.

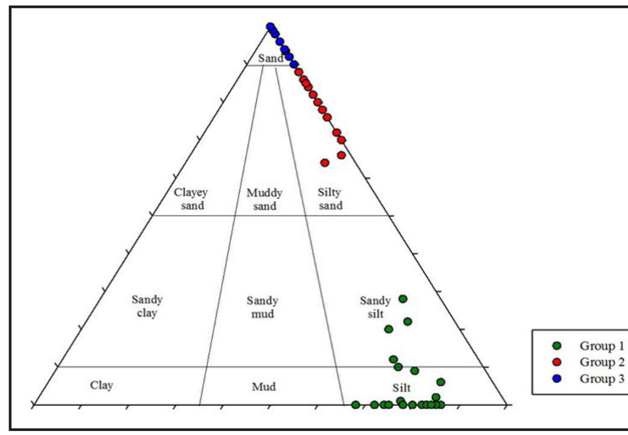

Figure 3: Nomenclature of sample based on Folk (1980) triangle diagram.

Samples were selected based on the distance of the sampling locations from shoreline and represent the whole study area. All fractions from fine to very coarse grain of each location were studied using a Hitachi Tabletop Microscope TM1000. The complete image and surface images were interpreted and classified using methods outlined in Margolis & Krinsley (1971), Krinsley & Doornkamp (1973), Margolis & Krinsley (1974) and Whalley & Krinsley (1974).

RESULTS

Grain size

Data from sieve analysis (Figure 2) show that the sediments of the Kelantan delta and adjacent shelf can be divided into three groups, i.e. group 1 (G1), group 2 (G2) and group 3 (G3). These two groups were classified based on (i) the percentage of sediment grain size and Folk ternary diagram, and (ii) the nature of the grain size cumulative curve (Figure 2).

G1 is dominated by silt size sediment ranging from 65-85%, followed by the clay percentage, which was between 8 percent to 32 percent, while the sand percentage was recorded as the lowest, ranging from 2 percent to 28 percent. According to Figure 3, G1 is scattered in the silt portion, represented by the samples from localities 1, 2, 3, 6, 7, 8, 21, 22, 23, 24, 25, 42, 43, 46, 61, 62 , 63, 64, 65, and silty sand by the samples from localities5, 44, 45 and 47.

The G2 sediments (Figure 3) are sand-dominated (64 to 88%) with subordinate silt (12 to 32%) and clay (0 to 6.5%). All the samples in this category had a poor grading curve type, while the Folk triangle shows that all the samples are scattered in the silty sand class, represented by samples from localities 9, 13, 17, 19, 28, 29, 30, 32, 33, 35, 36, 37 and 38.

G3 samples are dominated by sand (78 to 100 %), followed by silt (0 to 22%), while clay was not present. The G3 sediments shows a poor grading curve type, represented by samples from localities 10, 12, 14, 15, 16, 18, 26, 27, 31, 34, 39, 40, 48, 49, 50, 51, 52, 53, 54, 55, 56, and 59, while samples 11 and 41 indicated a type of uniform grading curve. Otherwise, samples 4, 57, 58 and 60 showed poor grading types, while sample 20 showed a good grading of curve. Based on the Folk nomination scheme (Figure 3), G3 can be classified under the sand group.

Mineralogy

The mineralogy and morphology of bottom sediments based on thin section study alone is not of much help in distinguishing the depositional environment and genetic sources of the sediment. In general, the distribution of mineralogy of sediments can be associated with the parent rock, while sediment morphology could be influenced by weathering and transportation processes. Polycrystalline quartz with suture boundaries can be inferred to have been originated from metamorphic parent rocks, whilst polycrystalline quartz with straight boundaries could have originated from igneous rocks (Blat & Cristie, 1963). Lithic fragments could be derived from weathering of sedimentary rocks, probably sandstone, mudstone and siltstone.

Quartz grain morphology is normally influenced by transportation history and erosion processes. When quartz

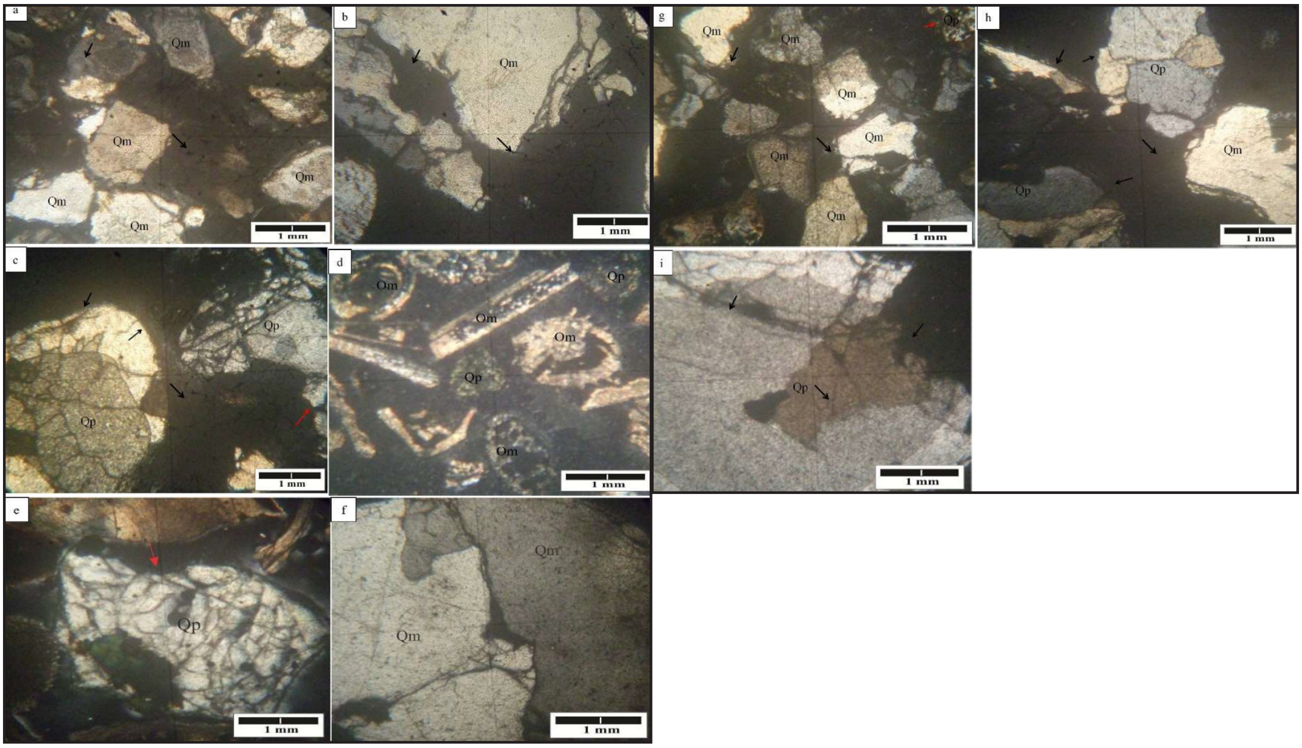

Figure 4: Mineralogy and morphology of bottom sediments: (a) fine-grained sand from locality 4; (b) medium grained sand fraction from locality 4; (c) coarse-grained sand fraction from locality 4; (d) fine-grained sand fraction from locality 33; (e) medium-grained sand fraction from locality 33; (f) coarse-grained sand fraction from locality 33; (g) fine-grained sand fraction from locality 60; (h) medium-grained sand fraction from locality 60; (i) coarse-grained sand fraction sample from locality 60. Qm- Monocrystalline quartz; Pq- polycrystalline quartz, Om- organic matter; black arrow show the suture boundary; red arrow show the straight boundary.

grains experience repeated episodes of transportation, erosion and deposition processes, they become more rounded and more spherical, while aggressive and rapid erosion and abrasion would produce more angular or sub-angular quartz grains. Due to the lack of information from the study of mineralogy and morphology from thin sections, the microscopic study of quartz grains focused on the texture of the quartz grain surface and the morphology of the quartz grain was carried out.

Surface texture and morphology of quartz

A broad range of grain characteristics was observed in the surface samples, which indicates the history recorded by the grains. Grains surfaces structure and textures present in all the sediment samples can be divided into six groups named as type A, type B, type C, type D, type E and type F. The grouping is subjective and based on the grain surface structure and texture and understanding about the weathering of parent materials and transportation processes experienced by sediments.

Type A grains (Figure 5(a)) show a very angular shape with no protruding edges but with an uneven tip. The fractured surfaces occur as planes at various angles without the presence of V marks. These characteristics might have been brought about as the grain was extensively modified by mechanical actions such as abrasion during the transportation process in a fluvial system.

Type B grains (Figure 5(b)) show irregular surfaces and edges with long fragments and fracture plane. The fresh-fracture surfaces present show many signs of V marks with lots of oriented etches and pits. These characteristics might indicate extensive mechanical actions on grains through grinding or abrasion.

Type C grains (Figure 5(c)) are well rounded with the occurrence of V marks and oriented etched pits on the surface, commonly with protruding edges and etched pits.

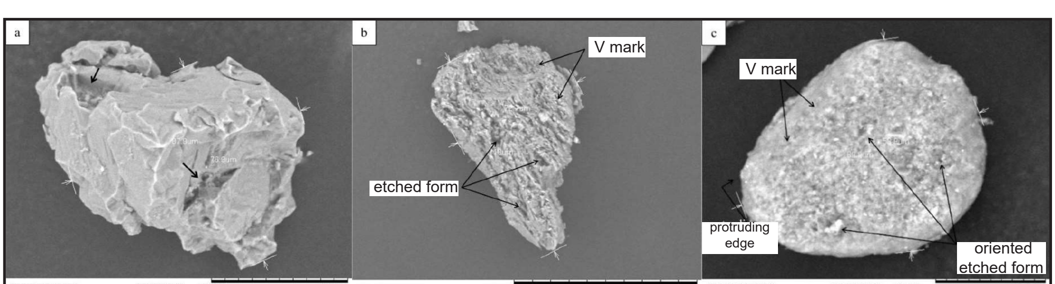

Figure 5: Scanning electron micrograph of typical grains: (a) type A grain from 23; (b) type B grain from 24 with elongated shape; (c) type C grain from 25.

The grains had experienced low energy relief imprinted the moderate to coarse texture on the grains' surface and altered the shape to uneven morphology.

Type D grains (Figure 6) have irregular breakages on the planar surface occurring at various angles especially along on the edges. The grain surfaces show a rough texture of irregular pits, adhering particles like silica with accentuated uneven grooves and V marks with the average size of less than 2μm. These might indicate aggressive and more extended mechanical actions than type A, B and C with extensive transportation and movement in the mid-ocean low energy over a long time.

Type E grains (Figures 7 and 8) show rounded and protruding edges with irregular shape and fracture and more well-rounded than type D. The rough surface shows the occurrence of oriented etched pits and V marks with a dimensional of <2μm, presence of detachments of small particles, commonly with trails of abrasions. These characteristics indicate that the grains had experienced moderate energy relief during transportation and continuous movement in the seafloor caused the grains to become rounded with uneven shape, angles and irregular surface texture.

Type F grains (Figure 9) have a very rough surface, irregular shaped with more rounded and protruding edges. The fresh-fractures surfaces show a lot of cracks which indicate the irregular breakage with detachments of small particles and etching holes of V marks with > 2μm dimension. Grains of this type showed a degree of high and continuous energy relief, probably happened during collision and aggressive abrasion between grains in the seafloor. The impact of the mechanical actions on the mid-ocean floor

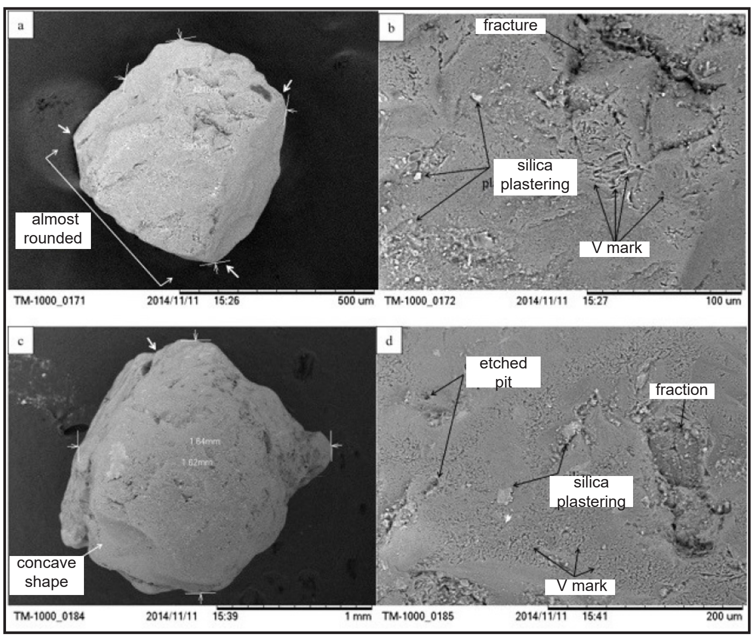

Figure 6: Scanning electron micrographs of grains: (a) type D grain, from locality 26 showing almost rounded shape; (b) close-up of grain surface (a); (c) type D grain from locality 26 showing concave shape; (d) close-up of grain surface (c).

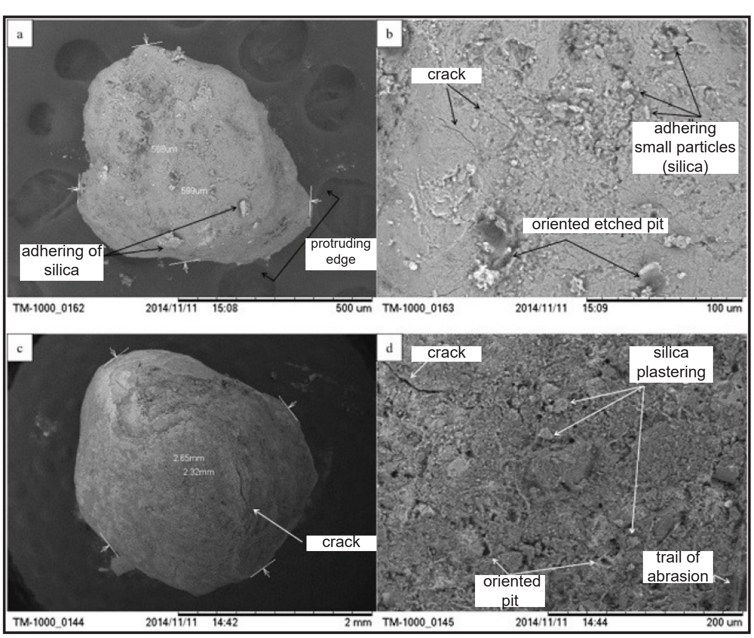

Figure 7: Scanning electron micrographs of grains: (a) type E grain, from locality 29 showing protruding edge and present of adhering of silica; (b) close-up of grain surface (a); (c) type E grain from locality 29 showing crack surface; (d) close-up of grains surface (c).

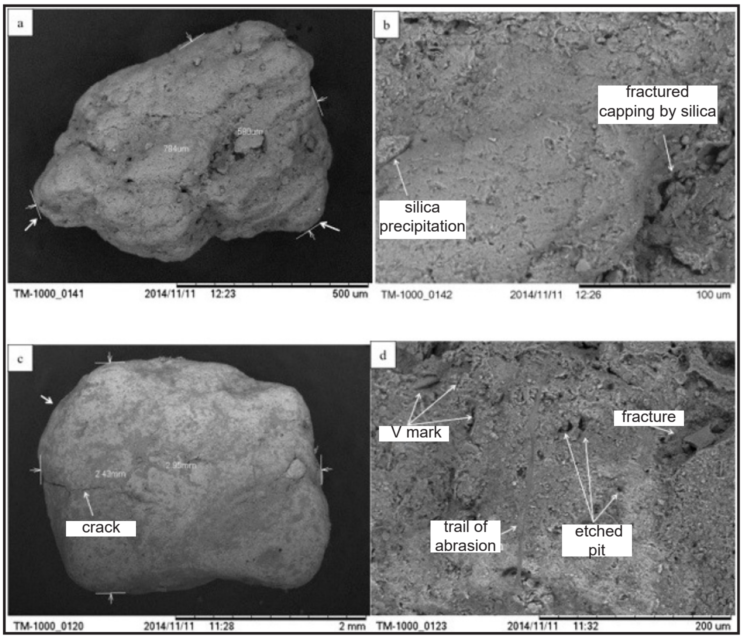

Figure 8: Scanning electron micrographs of grains: (a) type E grain, from locality 31 showing numerous protruding edges; (b) close-up of grain (a); (c) type E grain from locality 31 showing by crack on the surface; (d) close-up of grains (c).

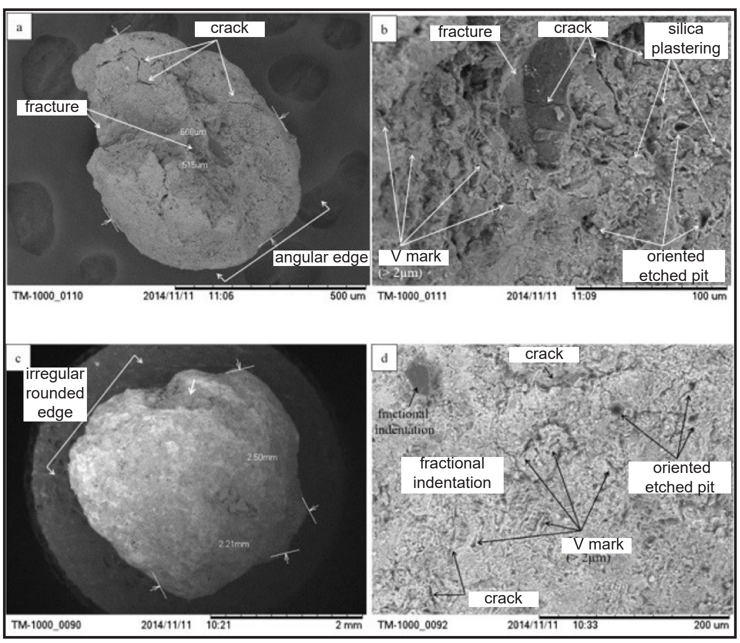

Figure 9: Scanning electron micrographs of grains: (a) type F grain, from locality 33 showing angular edge, fractures and numerous cracks; (b) close-up of grain in (a); (c) type F grain from locality 33 showing by irregular rounded edge; (d) close-up of grain in (c).

caused the original shape of the grains to transform to nearly round to very rough surface and irregular shape.

DISCUSSION

Bottom sediments from offshore Kelantan Delta can be divided into two sedimentological provinces (Figure 10, Table 2) assigned as province A and province B.

Province A

Province A sediments are dominated by clay and silt with average statistical parameters ranging from good sorting to very good sorting, very fine to fine skewness and very platykurtic. Mineralogical composition shows that province A contains monocrystalline (30 % to 40 %) and polycrystalline quartz (20 % to 40 %) and 10 % to 20 % feldspar and mica with an abundance of organic material. The angular morphology of quartz grains indicates that the grains experienced a short transportation history before being deposited in the area (Table 2).

The characteristics of province A sediments suggest that the Kelantan River was a major sediment contributor. These are interpreted as recently deposited sediments (Kravits, 1976). The polycrystalline quartz with suture boundaries could have originated from metamorphic rocks, while polycrystalline quartz with straight boundaries could be the products of weathering of igneous and metamorphic terrains. While monocrystalline quartz could have been derived from igneous parent rocks. The percentage of polycrystalline quartz can be used to determine the origin of quartz, especially the presence of polycrystalline quartz as an indicator for metamorphic rocks (Blat & Cristie, 1963 and Basu *et al*., 1975). The presence of monocrystalline and polycrystalline quartz with suture and straight boundaries in the samples collected in province A conclusively indicated that the sediments in this province were sourced from various types of rocks such as sedimentary rocks, metamorphic rocks, and granitic rocks.

After sediments were discharged by the Kelantan River, littoral drift process carried sediments to the northwestern part. The fine sediments released by the river were re-transported, which caused the mixing of fine sediments that were brought by the littoral drift from Pantai Mek Mas and Pulau Kundur and re-deposited in the area with minimum energy level (Koopsman, 1972; Zakaria, 1975; Raj, 1982; Kamal Roslan *et al*., 1997) (see Figure 11).

Geological and geographical conditions of the area also caused turbulent flow known as hyperpycnal flow to occur in front of the Kelantan River mouth. This phenomenon happened when the medium to coarse sediments transported in water was heavier than the energy flow, which caused the sediments to fall to the bottom and continue with the rolling movement on the seabed (Parsons *et al*., 2001). Meanwhile, the fine sediments were moved as plume in the water surface further before being deposited in low energy areas. According to Hill *et al*. (2007), evaluation of mechanism of sediments movement and transportation processes can provide a thorough understanding on the morphology changes and sediment distribution in the marine environment. The changes of sediment distribution reflected the impact from the integration of wave energy degree, water turbulence and the hydrodynamic processes that occurred during the transportation process. The implication of these integration processes generated the variable of sediments facies, demonstrated by the coarse grain size deposited in the delta areas and the fine sediments deposited in province A.

The highly durable quartz grains were capable to record the history and processes that occurred include erosion, transportation and deposition processes in the form of micro characters on the surface of grains. According to Douglas & Platt (1977), Darmody (1985), Marcelino & Stoops (1996) and Schulz & White (1999), the quartz surface morphology was a gauge history to obtain the age and weathering process experienced by the grains.

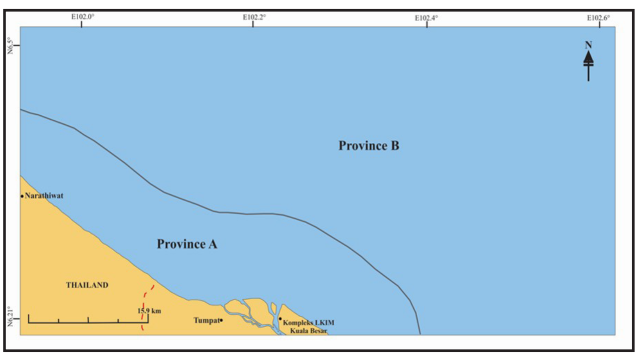

Figure 10: Sedimentological province of study area.

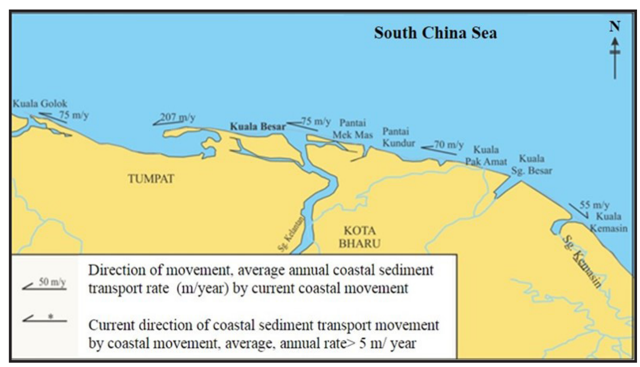

Figure 11: Illustration of coastal currents movements, modified from Raj, 1982.

Table 2: Principle characteristics of the sedimentological province.

Principal Characteristics	Province A	Province B
Sediment type	Clayey-silty-silty sand	Sandy silt-sand
Sand content	Low	High
Silt content	High	Moderate
Clay content	Moderate	Low
Sorting	Moderately well sorted – well sorted	Moderate – poor sorted
Skewness	Very fine- fine	Near symmetry- very coarse
Kurtosis	Very platykurtic	Very leptokurtic
Mineralogy	Monocrystalline and polycrystalline quartz, feldspar and mica	Monocrystalline and polycrystalline quartz, feldspar and mica
Morphology	Sub-angular angular- sub-rounded angular-rounded sub-rounded	Sub-angular angular- sub-rounded angular- rounded sub-rounded
Texture	V's mark dimension < 2 μm, irregular breakage and adhering particles, oriented etches pits	V's mark dimension > 2μm, silica globules detachments, rounded protruding edges, trail of abrasion, oriented etches pits, very rough surface
Relicts Sediments	No	Yes

Quartz grains with irregular shape, impact of abrasion and fractured plane indicate that the quartz grains have experienced a constant geological process for sometimes before being deposited in the shallow marine area. Sediments discharged by the Kelantan River got mixed with beach sediments caused by the littoral drift process and were deposited in the low energy area in the northwestern part. As pointed out by the evidences, the sediments in the province A were contributed by metamorphic, sedimentary and igneous rock from the hinterland of Kelantan state and mixed up with the beach sediment upon reaching the marine realms due to the seasonal littoral drift processes.

Province B

The characteristics of sediments from provinces B differed distinctively from the sediments of province A (see Table 1). Province B sediments showed a marked increase in sand and coarse silt, moderate to poorly sorted, near symmetry to very coarse skewed and very leptokurtic. From the mineralogical analysis, the sediments composed of monocrystalline and polycrystalline quartz mineral in the almost equal percentage with little presence of feldspar and mica ranging from 0 percent to 10 percent and the low content of lithic fragments and organic materials. Here, quartz grains show irregular shaped with more rounded protruding edges with very rough surfaces. Traces of abrasion and V marks with a dimension of >2 μm together with adhering particles of silica globules with oriented etched pits are common features of the grain surfaces.

Province B sediments originated from two sources; (i) Recent sediments (similar geological conditions to province A with the presence of small amount of fine sediments; and (ii) the relict sediments, verified by the presence of coarse sediments. Kravits (1976) defined relict sediments as sediments that were deposited a long time ago in different geological conditions. Thus, we interpret these relict sediments as being reworked from older sedimentary units.

Referring to the sedimentary processes, sediment with bigger dimension and heavier will be deposited in shorter distances from their origin, compared to the fine sediments because of energy degree and gravity attraction, generally capable to carry them to the continental shelf. Considering the fact that most fine sediments were deposited in province A and little was carried away to the continental shelf, it can be suggested that the coarse sediments eroded from the hinterland were mostly deposited in the Kelantan River channels and streams and little were carried further to be deposited in the delta areas. Meanwhile the fine sediments were taken further and deposited in province A and little in province B.

The ability of the river flow to carry the coarse sediment fraction further 30 km out on to the shelf is quite impossible. Thus the coarse sediments occurred in the province B is inferred to be the relict sediments that were deposited during the low sea level in the late Pleistocene and Holocene. According to Tjia (1992) the sea level was 100 meter or more below the present sea datum at about 18,000 years ago. The measurement of sea level changes using palynology data by Horton *et al*. (2005) found that the phenomenon distinctly happened during Holocene age around 9700 to 9250 cal. yr. BP until mid-Holocene, around 4850 to 4450 cal. yr. BP. The phenomenon had a great impact to the erosion and re-deposition of sediments in the coastal areas.

The analysis of quartz grains identified the high impact and continuous process history on the quartz surface which facilitated the sea-level changes modification theory of sedimentation process and re-deposition of the coarse coastal sediments in the continental shelf. With the characteristics such as V marks with dimension of > 2μm, etching pits and trail of abrasion indicates the quartz grains experienced a high impact of energy action which caused the nonstop collision, abrasion and breaking edges that commonly occurred on the sea floor (Krinsley & Doornkamp, 1973; Higgs, 1979; Hill & Nadeau, 1984; Hodel *et al*., 1988) since it was deposited. Mineralogical and textural analysis showed that the sediments in this province had undergone natural geological processes of transportation, erosion and deposition that formed spherical and nearly spherical morphology before being re-transported and re-deposited during the sea level increase.

From all the analyses, the surficial sediments collected from the seabed in the study area were influenced by geographical and geological factors, thus it can be concluded that the sediments in province A represent the Recent sediments originated from the present day terrestrial area in Kelantan Highland areas while the sediments that dominated province B are representing the relict sediments deposited during post-last glacial maximum transgression and subsequently reworked by currents.

CONCLUSION

This study indicates that based on the physical characteristics and distribution of bottom sediments, the depositional province can be divided into two; namely province A and province B. Sediments in province A which were mainly derived from the present day terrestrial areas in the Kelantan river catchment and mainly consists of clay and silt with minor amounts of fine to medium sand. The quartz grains that make the sand showed irregular shaped with fracture plane surfaces which could have been caused by processes of erosion, transportation before the sediments reach the marine realms.

Province B which covers the outer part of areas is primarily dominated by relict sediments which have been re-deposited during the transgressive period after the area experienced its lowest sea level during last glacial maximum around 18,000 years ago. Here, quartz grains are characterized by irregular grain morphology of sub-rounded with protruding edges with rough to very rough surface. The textures indicate that the sediments had experienced aggressive erosion and abrasion in high energy which occurred on the seafloor during the transgressive period before the sea-level reach its current position.

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