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MAJOR ELEMENTS AND OXIDES OF THE SOUTH CHINA SEA SURFACE SEDIMENTS OFF JOHOR COASTS

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Abstract This study determines the major elements, oxides, major oxide ratios and sediment texture off the coast of Johor, Malaysia. The sediment samples were collected using the Smith McIntyre grab operated on board of a vessel. The major elements and oxides were analyzed using the Scanning Electron Microscope and Energy Dispersive Spectroscopy (SEM-EDS) while the texture was determined using Boyoucous hydrometer method. The results showed that the dominant elements found in the sediments were Si, Al and Fe while the dominant oxide was SiO_2. The dominance of SiO_2 which is also the mineral called quartz indicates that the Johor coasts is highly siliceous. The dominance of quartz might be due to the weathering products of granite, which is the dominant rock found along the coastal area of East Coast of Peninsular Malaysia. Al_2O_3 and Fe_2O_3 are the next most abundant major oxide components after SiO_2 which indicates that feldspar and iron minerals are the common minerals found in the sediments. MgO and K_2O however, are the minor oxides found in the sediments. In addition, the SiO_2/Al_2O_3 ratio indicates that quartz and feldspar are present in roughly equal abundances in the sediments while the range of SiO_2/CaO ratios indicates that quartz has a much greater abundance than calcium carbonate in the sediments. The texture analysis showed that sandy clay loam covers almost 70% of the study area which indicates that the area is sandy. Clay texture is only found in station 30 which is located offshore.

Introduction

Marine sediments are highly fractionated crustal materials formed in the ocean from several sources. This fractionation is brought about by both chemical and physical processes at the earth's surface. Since the separation is rarely complete, the chemical compositions of many types of sediment are highly variable and it is difficult to formulate generalization about the average compositions and the processes which control the composition of particular sediments (Chaster and Aston, 1976). The material that is finally deposited in the marine sediment reservoir has undergone a complex journey before reaching its sea-bed sink. The sediments forming this reservoir represent, if not the ultimate end point, at least a major geological time scale halt in the global mobilization-transportation cycle. Knowledge of the chemical composition of this sediment reservoir is therefore important for an understanding of the global cycles of many elements (Roy Chester, 2000). Knowing the elemental composition and characteristics of marine sediments are critically important in determining the mineral deposits available in the area. It also reveals information on sediments provenance, transport pathways, depositional condition and the properties of the seafloor. Determination of elements and oxides is important in the sense that minerals present in the sediment can be known.

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Materials and Methods

Sampling site

The Johor state of Malaysia lies between 1°20"N and 2°35"N. It is the fifth largest state with an area of 18,984 km^2. It is also the southernmost state in Peninsular Malaysia being south of Melaka, Negeri Sembilan and Pahang and north of Singapore from which it is separated by the straits of Johor. It has a 400 km beach stretching on both the east and the west coast. Johor experience wet equatorial weather with monsoon rains from November until February blowing from the South China Sea. It is famous for the islands in eastern coast such as Pulau Sibu, Pulau Tinggi, Pulau Tengah, Pulau Besar, Pulau Hujong, Pulau Rawa, Pulau Pemanggil and Pulau Aur. The coastal area of eastern Johor is directly connected to the South China Sea (Wikipedia, 2006).

Collection of samples

The sediment samples were collected from 20 stations along the coasts of Johor (South China Sea) using a Smith McIntyre Grab operated on board the Fisheries Department vessel KL CERMIN. The sediments were placed in plastic bags and brought of to the laboratory for analysis. The locations of the sampling stations are presented in Fig. 1.

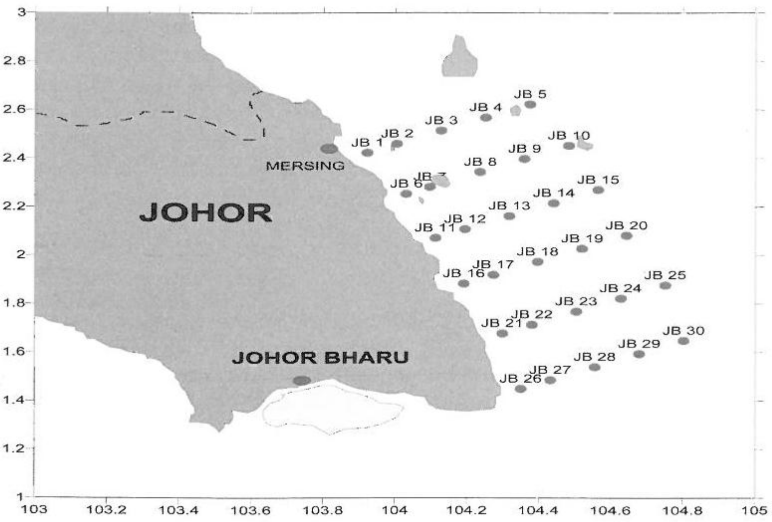


Figure 1. Location of sampling stations of the study area

Sediment Analysis

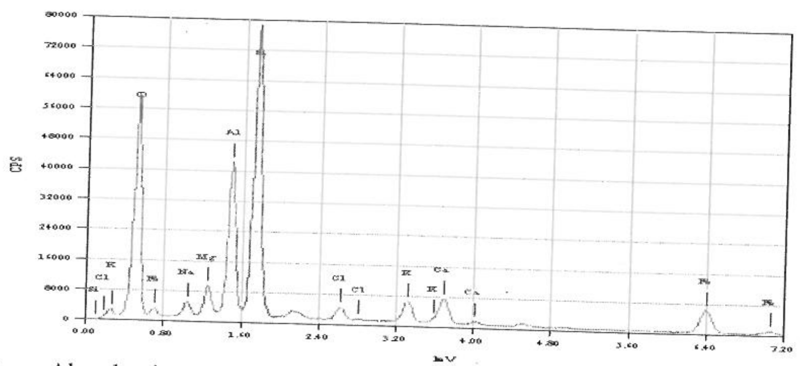
SEM-EDS Analysis

A pinched of the sediments was placed on a stub using conductive carbon. A blower was used to remove the sediments on the stub to ensure that the stub surrounding was clean. The stub containing the sample was then plaeced in the Auto fine coater JFC 1600 for coating. The sample was then processed using the Scanning Electron Microscope (SEM).

Results and Discussion

In general all elements found on the earth's crust are probably present in the marine sediments, although not all of them have yet been detected (Chaster and Aston, 1976). A total of 8 major elements have been determined and these include O, Na, Mg, Al, Si, K, Fe and Ca (Fig. 2.). Besides, 7 major oxides were also determined, namely; SiO_2, Al_2O_3, FeO, MgO, CaO, Na_2O, and K_2O (Fig. 3). The results of the major elements and oxides found in the sediments can be distinguished into three sections;

a) Oxygen is the dominant element in the sediments followed by Silicon and Aluminum in all the stations. Iron (Fe) is the fourth abundant element found in the sediments of all the stations. However, Na, Mg and K are the minor elements in the sediments of the study area. Na is not observed in sediments of station 24. But for station 15, Na has a much higher mass % as compared to those found in other stations. Ca is not present in sediments of station 20 while Titanium is found in station 26 only.
b) Silicon oxide (SiO_2) is the dominant oxide in the sediments followed by Al_2O_3 and FeO in all the stations. CaO is the fourth abundant major oxide found in the sediments. However, Na_2O, MgO and K_2O are the minor oxides found in the study area. CaO is not present in sediments of station 20 while TiO_2 is only found in station 26.
c) Major elements and oxides in sediments of the nearshore stations (stations 1, 11, 16, 22 and 26) and offshore stations (stations 5, 15, 20, 24 and 30) are more or less the same in their abundance (Fig. 4, 5, 7 & 8).



(Si = silicon; Al = aluminum; O = oxygen; Ca = calcium; K = potassium; Mg = magnesium; Fe = iron; Na = sodium; Cl = chlorine; Mn = manganese)

Figure 2. Spectrum of sample (station 1) in the study area

Major elements in sediments

Cornelis Klein and Cornelius (1993) indicated that eight elements make up approximately 99 percent by weight of the earth's crust such as; O (46.60%), Si (27.72%), Al (8.13%), Fe (5.00%), Ca (3.63%), Na (2.83%), K (2.59%) and Mg (2.09%). In general, the rank and average percentages of elements observed in sediments are comparable to the average chemical composition of the earth's crust' which are 42% for O, 23% for Si, 13% for Al, 11% for Fe, 4% for Ca, 2% for Na, 3% for K and 3% for Mg (Fig. 3). This might be due to the composition of the earth's crust which consists of igneous, metamorphic and sedimentary rocks which are the origin of the sediments upon weathering. Generally, the high amount of oxygen in sediments might be due to its presence everywhere (obiquitous). Silicon (Si), which are susceptible to chemical weathering was the second abundant element in the sediments. It is an important constituent of many igneous, metamorphic and sedimentary rocks. The third element is Aluminum (Al). The distribution of aluminum in sediments is almost exclusively controlled by the input of detrital aluminum-silicates to the ocean from the continents (Chaster and Aston, 1976). Because aluminum in sediments is largely located in detrital minerals it has been used as an indicator of the amount of terrigenous debris in the sediments (Arrhenius, 1952; Landergen, 1964). According to Antonina (2001) point out that aluminum is derived mainly from alumino-silicates, generally of terrigenous origin and is immobile in the marine environment. Si, Al and Fe which are the insoluble and fusible elements easily accumulate in clastic sediments and is therefore dominant in sediments of the study area. Iron (Fe) is transported to the ocean in association with terrigenous solids and from the continents in association with minerals such as feldspar, olivine, augite, hornblende, magnetite and ilmenite (Goldberg and Griffin, 1964). Mg and K are the trace elements which contribute less than 3% of the sediments found in the study area. These elements are both volatile and lithophile elements and therefore poorly contained in the sediments. On the other hand, Na and Ca have an average percentage of 3.35 and 4.24%, respectively. Nearshore and offshore sediments have similar concentrations of Na and K and the bulk of these elements are associated with clay minerals (Welby, 1958; Heier and Adams, 1964). The distribution of Ca and to a lesser extent to that of Mg are largely controlled by biological processes. Both Ca and Mg found in many crustal minerals such as clay minerals, feldspar, etc. are transported to the ocean in terrestrial detritus (Chaster and Aston, 1976).

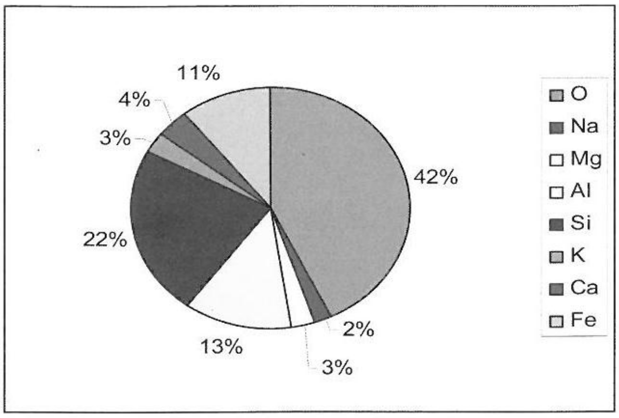


Figure 3. Average % of major elements in sediments of the study area

Comparing the results of the elements' percentage of the nearshore and offshore stations revealed that the elements of the nearshore and offshore stations are relatively of equal abundance (Fig. 4 & 5). However, there was no significant difference observed ($p < 0.05$) between nearshore and offshore stations in terms of the elements studied except for Na which revealed significant differences.

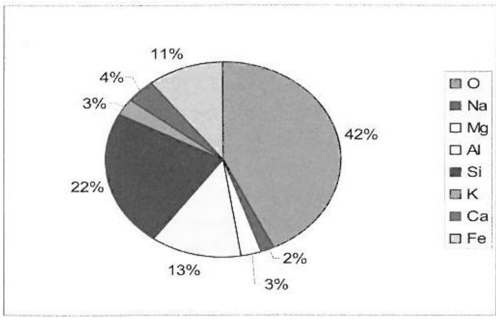


Figure 4. Average % of major elements in nearshore sediments of the study area

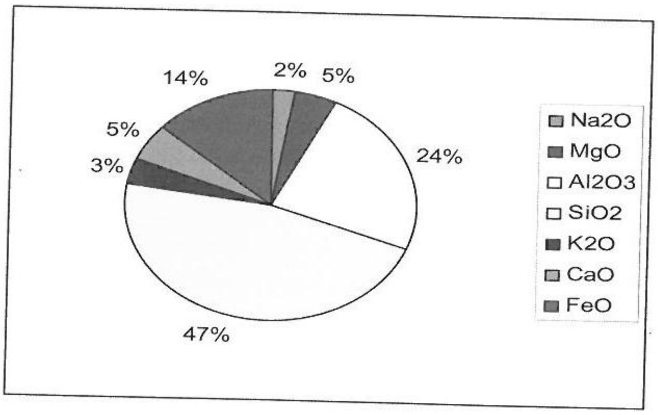


Figure 5. Average % of major oxides in nearshore sediments of the study area

Major oxides in sediments

Many studies have shown that particle size and geochemical characteristics of sediments can provide sensitive indicators of sediment provenance, transport pathways and depositional conditions (McLaren, 1981; Pye, 1982; McLaren and Bowles, 1985; Gao and Collins, 1992; Pye, 1994; Gao and Collins, 1994; Winspear and Pye, 1995; Winspear and Pye, 1996; Knight *et al.*, 2002 and Saye *et al.*, in press).

Results showed that in general, the sediments of the study area are highly siliceous (SiO_2) with an average percentage of 47% followed by Al_2O_3 and FeO with an average percentage of 24% and 14%, respectively (Fig. 6). However, CaO is the fourth abundant major oxide found in the sediments with an average percentage of 5% and Na_2O has an average percentage of 4.54%. On the other hand MgO and K_2O had an average percentages of 5% and 3%, respectively.

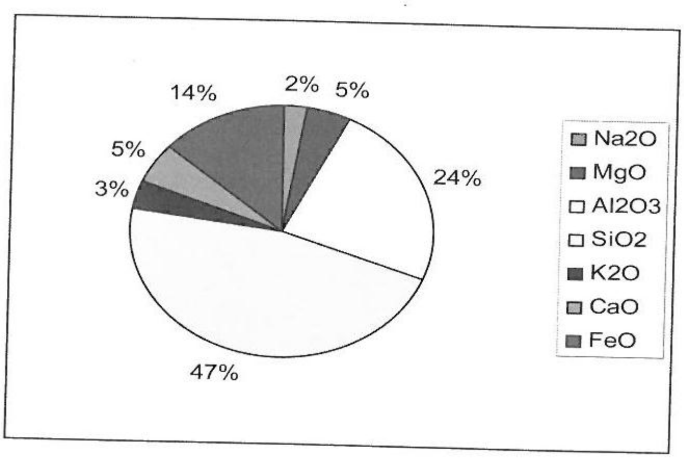


Figure 6. Average % of major oxides in sediments of the study area

Quartz (SiO_2) is the dominant oxide observed in the study area (Fig. 6). The dominance of quartz might be due to the weathering products of granite, which is the dominant rock found along the coastal area of East Coast of Peninsular Malaysia (Antonina, 2001). According to Francis Albarede (2003), the erosion of granite yields clay minerals and quartz grains, and add to the dissolved load of run-off water; the clay accumulates on the ocean floor and the quartz is deposited as sandstone on the continental shelf or slope.

Aluminum oxide (Al_2O_3) is the next most abundant major oxide components after SiO_2. Richard A. Davis (1985) indicated that quartz and aluminum oxide are dominant because of their chemical and physical durability with respect to other minerals. Quartz and aluminum oxide may go through several cycles of deposition, erosion, and accumulation. On the other hand, Al_2O_3 and FeO, which constitute an important portion of the sediments, indicate that feldspar and iron minerals are common minerals found or present in sediments of the study area. CaO contents in the sediments indicated the presence of shell fragments and foraminifera although it is not very abundant (5%). The moderately high percentage of CaO in the sediments is a reflection on the high shell fragments that can be found in the sediments.

Comparing the results of average major oxides for the nearshore stations and offshore stations in the study area (Fig. 7 & 8) indicate that major oxides in the sediments of the nearshore and offshore stations are relatively equal in its abundance. Analysis of variance (ANOVA) using an independent *t*-test shows that there is no significant difference ($p < 0.05$) between nearshore and offshore stations in terms of most of the oxides determined except for Na_2O which shows significant differences occur between nearshore and offshore stations. The sediments in the study area are mostly derived from adjacent land sources and transported by two major rivers (Sungai Endau and Sedili). Hence, there was no systematic variation in sediment's chemical compositions with respect to distance from the shore.

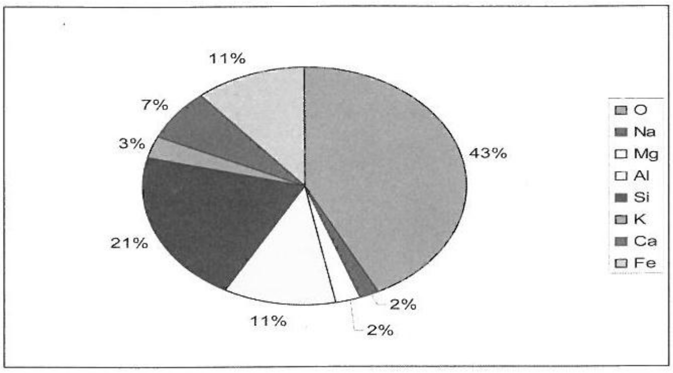


Figure 7. Average % of major elements in offshore sediments of the study area

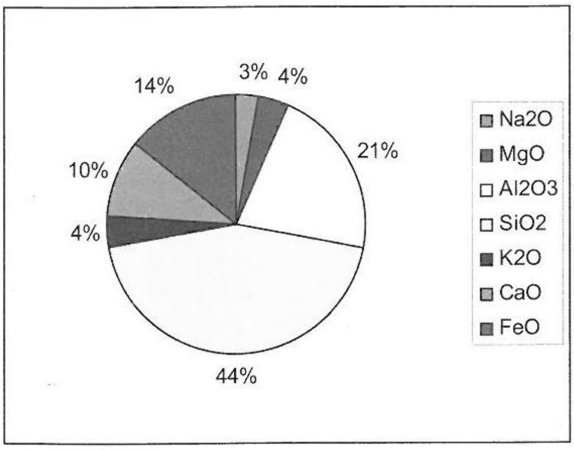


Figure 8. Average % of major oxides in offshore sediments of the study area

Conclusion

Generally the sediments found in the coastal area of Johor, off the South China Sea are relatively coarse and highly siliceous (SiO_2) which is a reflection to the dominant rock along the coastal areas of east coast of Peninsular Malaysia which is granite.

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