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Quartz and Dolomite Content Variations and Climate Changes in Late Pleistocene Sediments of the North Arabian Sea

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ABSTRACT: *Deep sea sediment core CD 1730 collected onboard Charles Darwin cruise CD 18/37(1986) from the Arabian Sea off Oman continental margin is analysed for reconstruction of late Pleistocene Paleoclimate. Oxygen isotope record of this core has been used for chronostratigraphy. The core shows depositional history of last 140,000 years BP and indicate 6 isotopic stages. In this paper changes in terrigenous material i.e. quartz and dolomite content in cold and warm climatic stages have been discussed. Since quartz and dolomite are detrital in nature, their changes in the core reflect a control of regional climatic patterns in glacial and interglacial stages. Quartz content on carbonate free basis varies in core from 6 to 11% and dolomite content on carbonate free basis varies from 1 to 10%.*

INTRODUCTION

The Arabian Sea is a repository for the continental derived material originated from the surrounding land mass. Geomorphologically, the neighbouring continents are arid lands where effects of climate variation are very severe. The Arabian Peninsula has, been identified by Idso (1976) as one of five major world regions where dust storm generation is very intense. Middleton (1986 a; b) has noted that prevailing northwesterly winds in the area transport this dust load towards the Arabian Sea. Major dust trajectories and satellite images clearly show that material picked up from the north, in northeast Africa, Mesopotamia, Arabian deserts and Iran, is transported towards the sea (Grigoryev et al., 1 980; Coudie-Gaussen, 1984; Sirocko and Sarnthein, 1989). Such consistent trends in transport directions have also been reported from marine aerosol investigation in the area (Aston et al., 1973; Prodi et al., 1983, Chester et al., 1985). Several studies of surface sediments in the area (Emery, 1956; Sugden, 1963; Stewart et al., 1965; Kolla and Biscay, 1977; Kolla et al,, 1981; Khalaf and Al-Hashash, 1983; Sirocko and Sarnthein, 1989, Khan,1989) have confirmed that prevailing winds are predominant in transporting these sediments. The latest quantitative study (Sirocko and Sarnthein, 1989) using satellite data and sediment cores, has enforced the importance of dust transport in this area. They showed that amount of aerosol discharge in 1979 (115-215) x 10^6 t/y broadly equates with the average late Holoceile aeolian flux in deep sea sediments of Arabian Sea (80-100) x 10^6 t/y. The dust input studies in NW Arabian Sea sediments on a longer time scale were reported by Clemens and Prell (1990,1991), deMenocal et al. (l991) Khan and Price (1992). Studies (Sirocko and Sarnthein, 1989, Khan, 1989, demetiocal et al.,1991) used quartz and dolomite as proxy of dust. In a longer time record from ODP site 722 deMenocal et al. (1991) found that quartz and dolomite abundance strongly correlates with magnetic susceptibilty. A good correlation between dust grain size (an indicator of wind strength) and G.bolloildes (an indicator of monsoon upwelling) was notes (Clemens and Prell (1990). Sediment trap data from the western Arabian Sea (Nair et al., 1989) has demonstrated that 80% of the annual lithogenic flux to the north west Arabian sea occurs during south west monsoon.

In this paper changes in quartz and dolomite contents during glacial and interglacial periods in N.W. Arabian Sea sediments are discussed. Core CD1730 collected from oceanic depth off Oman coast during R/V Charles Darwin Cruise 86/17, record a oeruid if accynykatuib extebdubg ti 140,000 years BP. Variations in climatic conditions during this period are seen in this sediment core. The quartz and dolomite are the major terrigenous component in the sediments and have been used as indicators of paleoclimate. Quartz and dolomite content and their variations with respect to time, in this study strongly confirms the previously published findings.

STUDY AREA

Meteorology

The Northwestern Arabian Sea is characterized by seasonal changes in the atmospheric circulation known as monsoons. This monsoonal circulation is mainly controlled by the differential heating of land and ocean. In the summer the continents are transformed into centres of lower pressure, while in the winter they are comparatively cooler than the warm oceans and consequently are areas of high pressure. Hence, during winter a pressure gradient is established which creates a NE monsoon winds directed from India, Pakistan and Afghanistan towards the Arabian Sea (Fig. 1).

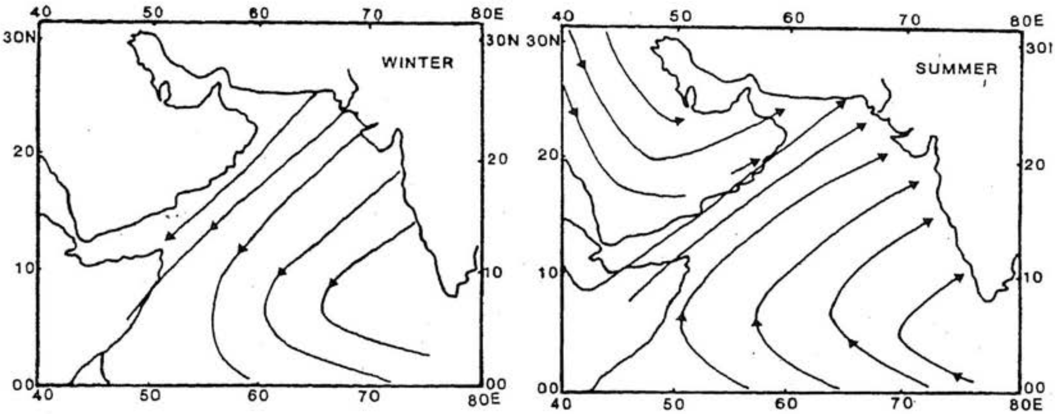


Fig. 1. Seasonal Surface winds pattern for Arabian Sea (Hastenrath and Lamb, 1980).

During winter gentle winds blow with speed of 23m/sec in the Arabian Sea (Ramage, 1969). In summer (June-August the intensive warming of the continental landmass Crates a low pressure in Asia. This results in a land directed strong southwesterly monsoon over the Arabian Sea (Fig. 1). Wind speeds up to 515m/sec have been recorded during summer (Ramage et al., 1972). During summer dust load is very high (MsDonald, 1938. Ackerman and Cox, 1982; Sirocko and Sarnthein, 1989). Occasional major dust storms also occur in this region (Foda et al., 1985; Chen, 1986; Ackerman and Cox, 1988).

MATERIAL AND METHODS

Materials

A piston core CD 1730 collected onboard Charles Darwin cruise 18/37 of the North Arabian Sea has been analysed in this study. The location of the core is shown in Fig. 2.

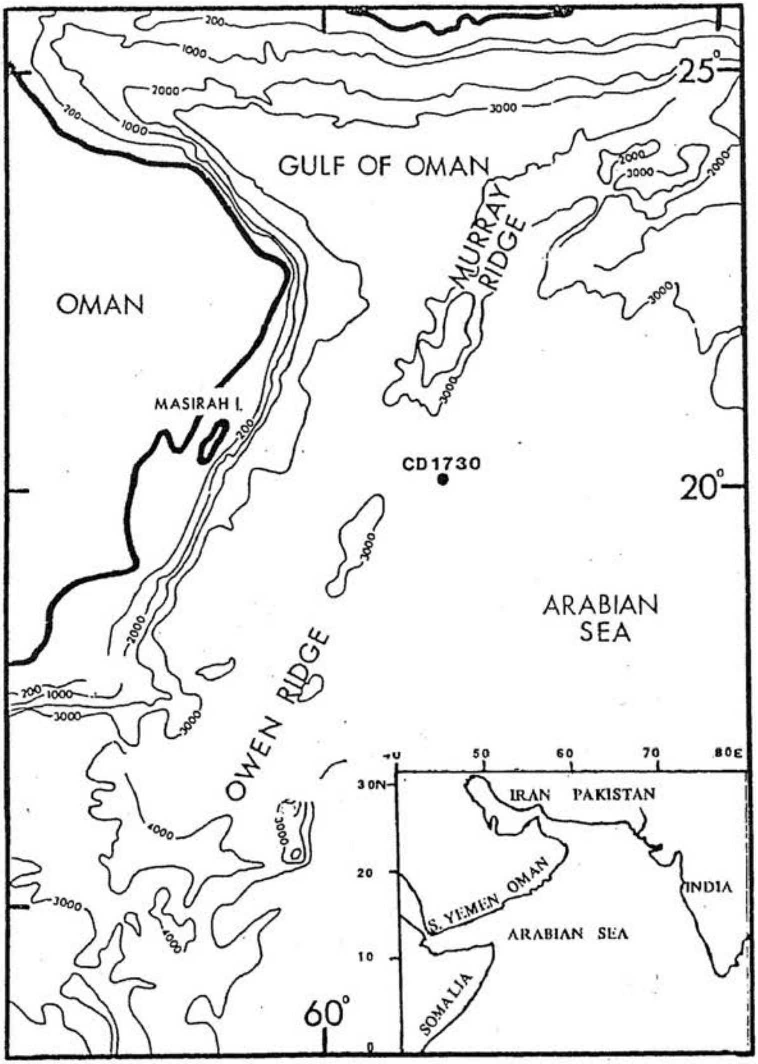
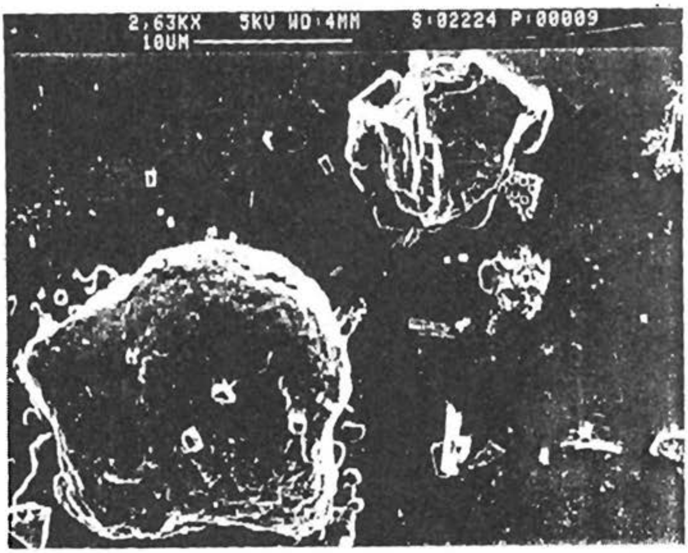


Fig. 2. Location map of sediment core CD 1730 from Northwestern Arabian Sea.

This core is 8 meters in length and raised from a water depth of 3580 meters. The core sediments are composed of clay to silt size terrigenous and biogenic constituents . The colour of the sediments varies from pale yellow, pale greenish to olive green and greyish green. Examination of smear, slides show that the terrigenous fraction in the cores contain significant amount of silt site quartz, feldspar and dolomite, SEM photographs show that quartz grains are usually rounded and pitted and dolomite occurs as rhomb shaped grains (Fig. 3).

a)



b)

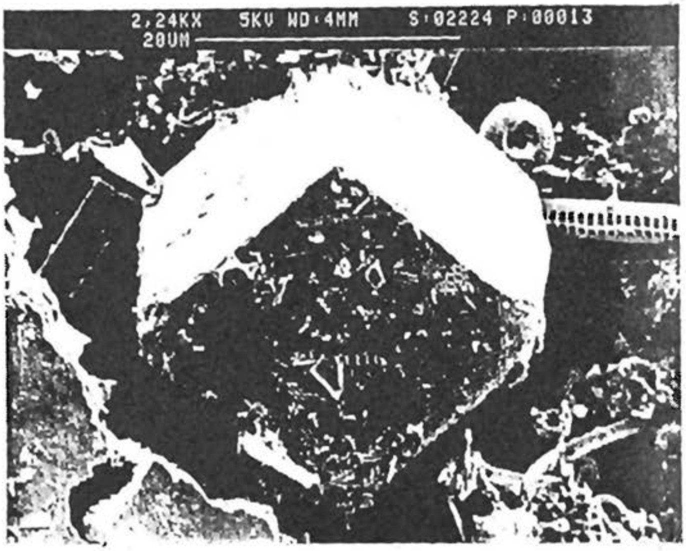


Fig. 3. SEM photographs showing detrital grains in surface sediments from Arabian Sea (a) Pitted rounded quartz (b) Euhedral dolomite.

SAMPLING

Sediments are generally of uniform lithology and sampled at an interval of 10 cm to the base of core. Dried samples were ground to a fine powder (<2μ) and subsequently subjected to XRF analysis for Si determination and gasometry for dolomite determination.

QUARTZ CONTENT

Silica in marine sediments mostly occurs as quartz and Si/Al ratio in sediments is generally 3.0 (Bostrom et al., 1972). The values of more than 3.0 have been suggested due to quartz derived Silica. Si/Al ration in, sediment cores from Arabian Sea show that it ranges between

3 and 4.5 (Khan, 1989). The excess Si above the normal Si/Al ration of 3.0 has been computed as quartz. The quartz content is calculated from the chemistry of Si analysed by XRF. Since the core is shown to contain 12% biogenic silica (Khan, 1989), the following relationship is used for calculating the quartz content.

Quartz (%) = Total Si - (Total Al x Si/A1*) - Biogenic Si %

*Si/Al = 2.5 (Assumed composition of aluminosilicates)

DOLOMITE CONTENT

Dolomite content in the sediments analysed using a carbonate bomb (Muller and Gastner, 1971). This works on the principle of gasometry; it measures the CO_2, gas produced by Hcl dissolving the carbonate in the ground and pre-weighed sediment powder. The analytical results are within a range of 1% accuracy and are presented on carbonate free basis.

CHRONOSTRATIGRAPHY

Chronostratigraphy is based on the Oxygen isotope record (Khan, 1995). The stable oxygen isotope analysis has been performed on the plankton for a,omofera Globigerinoides sacculifer. The oxygen isotope data shows the isotopic stages 1 through 6 of Emiliani (1955). Odd and even numbers have been designated to progressive glacial and interglacial events, the Holocene has been represented by stage 1. The odd numbers show the warm interglacial period and even numbers denotes the cold glacial times. The Age boundaries of different isotopic stages have been placed following Imbrie et al. (1984).

RESULTS

Quartz

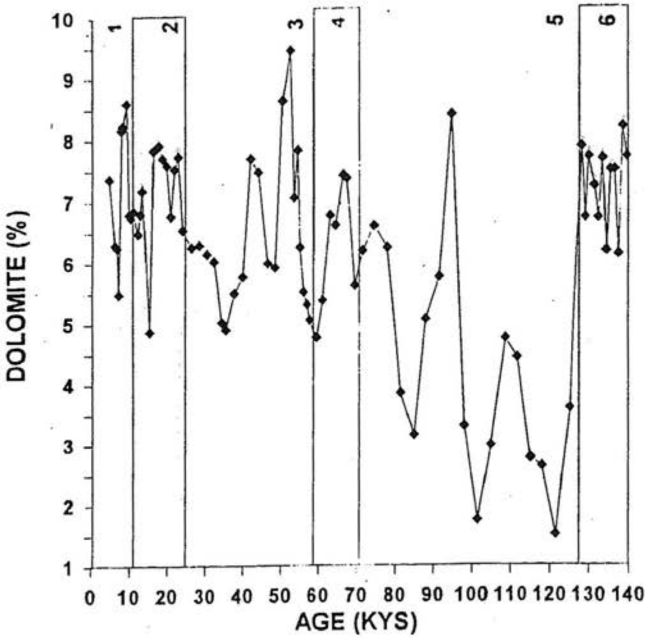
Quartz contents (carbonate free basis) and its oscillation with time is shown in Fig. 4. Quartz content varies between 7 and 11% in the investigated core. The Holocene stage 1 shows 9% quartz. Interglacial stages 3 & 5 show invariable high quartz i.e.$\geq$ 10% as compared to glacial stages. Higher content of quartz up to 10% occurs in stage 2. In glacial stages (4, 6) tile quartz is generally low relative to glacial stage 2. Towards the top of stage 6 quartz values decreases. The highest value of 11% quartz is seen around 50,000 years BP in stage 3. The most significant trend seen in stage 5 is such that quartz exhibits a steady increase toward younger interglacial and younger glacial stages.

Dolomite

The distribution of dolomite temporally follows the quartz and shows a trend of increase from stage 5 to stage 1 (Fig.4). The high dolomite 7-8% occurs in stages 2, 4 and 6. Fluctuation in dolomite observed in glacial and interglacial stages is similar to that of quartz except in stage 6 which shows highest dolomite i.e. 8%. A marked minima in dolomite occurred around 120,000 years BP and 100,000 years. Dolomite shows a well defined increase from this latter position to the top of stage 2. In the middle of stage 5 dolomite content increases from 2 % to 8% and then fails to 3% in upper part. From this latter point dolomite increases up to 6% before a small fall at stage boundary 4/5. In early stage 3 an increase from 5 % to 9 % occurs. In middle of stage 3 dolomite varies between 5 and 7%. Holocene stage 1 shows peak value of dolomite around 9,000 years BP and then decreases upward to 5%. In stage 3 and 2 dolomite steadily increases upward and discontinue in the upper parts. Highest value occurs in stage 3 i.e. > 9% Glacial stage 4 represents a cold period of very short duration; ~10,000 years with 6-7% dolomite content .

DISCUSSION

Quartz and dolomite are largely derived from terrigenous sources and are common in marine aerosol (Prospero and Bontti, 1969, Blank et al., 1985; Chester et al., 1985). Sirocko and Sarnthein (1989) documented the accumulation rates of dolomite and outlined the transport



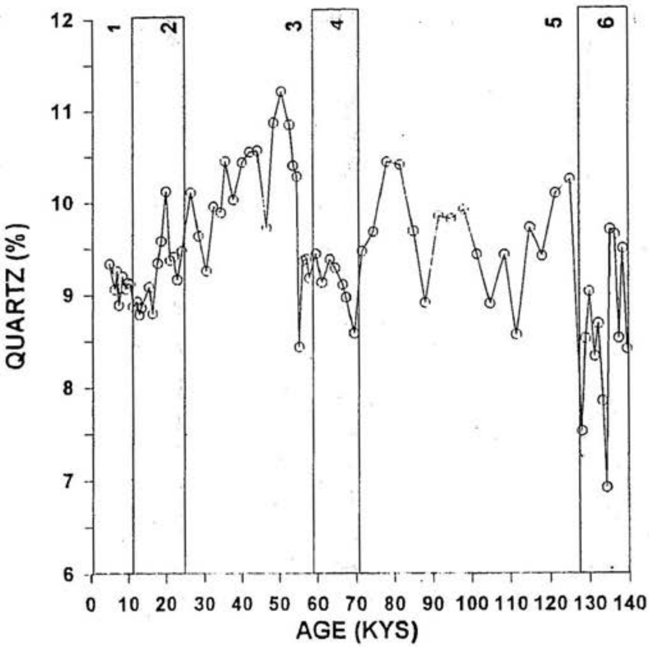


Fig. 4. Quartz and dolomite variations in glacial and interglacial stages in core CD-1730 from Northwestern Arabian Sea.

direction from the Oman coast to the south. It has been shown that sediments accumulating beneath aerosol deposition are highly consistent with that of the composition of the aerosol (Blank et al., 1985). Tile chemical composition of the dust particles collected from the Indian ocean shows a significantly higher concentrations of Al, Si, K, Mg and Fe (Prodi, et al., 1983). Silica in sediments from Arabian sea has been shown to be derived from lithogenic material (Shanker et al., 1987; Khan, 1989). A number of studies (Stewart et al., 1965; Stoffers and Ross, 1979; Sirocko and Sarnthein, 1989, Khan, 1989) show that silt-size dolomite, along with quartz and clay minerals, occurs in Arabian Sea sediments in substantial quantities.

The surface features of quartz and dolomite (Fig. 3a & 3b) reflect all aeolian transport. Their variations down the core shown in Figure.4, however, suggest the climatic control. A relationship between climate and wind intensity is evident in the winter/summer climatic cycles (Lamb, 1966). In the studied area, seasonal variation in wind intensity and the subsequent effect on dust transport is well documented (Prospero, 1981; Middleton, 1986; Sirocko and Sarnthein, 1989; Ramaswamy et al., 1991).

In the analysed core the overall trends seen in the oscillation of the quartz and dolomite are consistent during all isotopic stages throughout the last 140,000 years. Generally both profiles of quartz and dolomite are smooth except a few erratic points. There is progressive increase in quartz and dolomite irrespective of glacial and interglacial stages. This suggests that the source area and mode of transportation has not changed through time. In interglacial stages 3 and 5 quartz and dolomite content increases with intermittent decrease at different levels which indicates an increased supply of continental derived material to Arabian sea in warm periods i.e. ititerglacials. In glacial stages shown here by even numbers (2,4,6) quartz and dolomite contents also show an increase with uniform trend except in stage 6. Isotopic cold stage 6 show high dolomite i.e. 8% and in the same stage quartz peaks are relatively less pronounced. In last glacial maximum (-18000 years BP) stage 2, quartz and dolomite shows similar trend with values up to I 0% and 8%, respectively. The changes in the values during cold and warm stages could only be explained either by the effectiveness of the transporting agent (i.e. winds), or by the climatic conditions of the source areas. The consistent trends of quartz and dolomite show that the climatic of the source area has retained and during their deposition. The quartz and dolomite in the sediments have been identified as eolian material. The variations in content in different climatic stages imply that the local winds system has greater control in transporting eolian material. Quartz and dolomite content both display an increased at 18,000 years BP which steadily decreases upward. There is much information available on paleo-environment for world for this period. The increased values observed in this stage imply widespread aridity on the continents bordering the Arabian sea. High quartz content during stage 2 observed in this study is in close agreement with high quartz content noted by Kolla and Biscay (1977) ill the area. Following these workers, high quartz in the Arabian sea suggest increased aridity during last glacial maximum. Continental evidence from the area show that at this time the Persian Gulf region (Sarnthein and Diesetr, 1977) and Rajasthan (Bryson and Swain, 1981) were dry, the Zagros mountains in the north were drier than they are today (Wrigth et al., 1967). Glacial stages 4 and 6 are low in quartz arid dolomite relative to glacial stage 2. However, their increasing trends, in these stages support the idea that glacial environment was arid like stage 2, arid resulted in higher dust transport in tile Arabian sea. The high dolomite content in stage 6 probably indicates relatively increased supply of dolomite from the desiccation of coastal sabkhas deposits.

During interglacial stages 3 and 5 a general increases occurs in quartz and dolomite arid may represent strong s.w monsoon as supported by Clemens and Prell (1991) from increased grain size and G.bolloides record. The oceanic records of the monsoon variations in Arabian sea shows stronger s.w monsoon during interglacial times (Prell,1984; Prell and Kutzbacli,1987; Khan, 1995). Today the s.w monsoon winds blow with speed 5-15m/sec (Ramage et al., 1972). Sediments trap data also signifies high lithogenic fluxes during these times (Ramaswamy et al., 1991). All these evidences suggest that the quartz and dolomite changes ill glacial arid interglacial stages in core CD 1730 are a result of changing s.w monsoon. Stronger winds during monsoon in interglacial stages 3 arid 5 transport large amount of aeolian material from the neighbouring source areas. Holocene sediment record of core CD 1730 is incomplete. In the Holocene stage I there is some evidence of variations of quartz arid dolomite content in the core. The trend shown around 9,000 years BP reflects an increase in quartz and dolomite. Climatic modelling for 9,000 years BP have documented strong s.w monsoon (Kutzbach, 1981; Prell arid Kutzbach, 1987). Sirocko and Sarnthein (1989) in this area noted similar mineralogical compositions of the Holocene sediments and suggested transport by prevailing winds crossing the Oman.

Today the seasonal variation associated with monsoon system of the area shows tile extremes of dust load. Major dust haze observed oil the Arabian Sea occur during June, July, August (McDonald, 1938; Prospero, 1981; Middleton, 1986a, b). During this season dust outbreaks are common (Foda et al., 1985; Chen, 1986; Ackerman & Cox, 1988), and along both the African and Arabian coasts substantial dust transport, including storms have been reported (Sirocko and Sarnthein, 1989).

From the sediments record in this study it has been established that seasonal reversal of wind system are the most important factor in controlling the distribution of lithogenic Materials in Arabian Sea sediments. Depending on their intensity, it may be expected that winds transport varying amount of terrigenous material. The changes in quartz and dolomite content with respect to time as shown in Figure 4 may reflect past changes ill the intensity of s.w monsoon winds relating to the climatic oscillations of the late Pleistocene. The strength of winds, however, is difficult to discern from the present data.

CONCLUSIONS

In this study the changes in quartz variation shows a significant correspondence with dolomite in temporal distribution. In different climatic stages, interglacial events 3 and 5 tend to show high quartz and dolomite. The high quartz and dolomite are seen in glacial stages 2. In other glacial stages (4 and 6) the quartz and dolomite content is relatively low.

Fluctuation of quartz content in marine sediments reflects the climatic patterns of the surrounding areas (Bowles, 1975; Theide et al., 1982). Likewise, the changes in the quartz and dolomite content observed in different climatic stages recognised in this study are most likely reflecting the climatic condition prevailing at those titles. Based on this following conclusions can be drawn.

Aeolian quartz and dolomite are the most important and predominant minerals in sediments depositing in north western Arabian sea.

Temporal variations in the quartz and dolomite content suggest a climatic control. Changes in glacial and interglacial stages indicate a pronounced influence of climatic patterns of s.w monsoons during cold and warm stages.

Seasonal and local winds have been major contributor in the dust transport towards Arabian sea.

Stronger s.w monsoon during Interglacial stages 3 and 5 transport large amount of lithogenic material from the surrounding deserts to the northwestern Arabian sea.

Glacial times typify dry continental conditions. In isotopic stages 2,4 and 6 quartz and dolomite content tends to increase which signify the high aridity of the source areas.

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