

## REVIEW ARTICLE

# OFFSHORE GEOLOGY OF PAKISTAN AND NON-LIVING RESOURCE PROSPECTS

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**ABSTRACT:** Offshore geology of Pakistan is characterized by active and passive continental margins. These continental margins show very unique features such as an active Makran subduction zone in the west and the Indus delta and a submarine fan in the east. The geology of these features of Pakistan EEZ is inadequately known. This is a major obstacle in exploring mineral resources. Detailed study of coastal and shelf geology is needed for better understanding of the geology of the area and comprehensive evolution of its non living resource potential. An understanding of the geological events including tectonic movements, sedimentation processes and geochemical history that comprise the geological history is very important to help in identification and estimation of resources. In Pakistan EEZ applying the current technology and undertaking research work to understand the seafloor features and mineral deposits associated with it will be very fruitful.

**KEY WORDS:** Offshore geology, non-living resources, Pakistan EEZ.

## INTRODUCTION

Pakistan coast is about 900 km long from east to west. Its Exclusive Economic Zone (EEZ) is about the 240,000 sq. km. The coastal and offshore geology of Pakistan tectonically exhibit both active and passive margin features. The Makran coast and Makran continental margin are active whereas the Indus coast and offshore Indus basin are geologically passive. The geological features of the Pakistan EEZ are very promising for exploration of non-living marine resources. These resource potential need to be evaluated for which detailed geological investigations are required. In this paper an account of the offshore geology of the Pakistan Exclusive Economic Zone and its resource potential is presented.

## GEOLOGY OF THE ARABIAN SEA

The Pakistan Exclusive Economic Zone (EEZ) is an offshore area of the northern Arabian Sea. Before describing its non-living resources, it is essential to know the details of the geological characteristics of the Arabian Sea. The Arabian Sea is a geological young feature. It was produced in the last 65 million years after the closing of a shallow sea known as Tethys. Geological history of the Arabian Sea starts with the breakup of the super-continent, Gondwanaland, in the Jurassic age about 200 million years ago. In the Jurassic, India, Madagascar, Antarctica and Africa were a single landmass known as Gondwanaland. In the late Jurassic, 160 millions years ago, initially India, Madagascar and Antarctica separated from Africa (Rabinowitz *et al*, 1983). This separation was

followed by northward movement of the Indian plate. The northward migrating Indian plate collided with Eurasia some 50 million years ago. The continued northward movement of the Indian plate closed the Tethys sea and the Arabian Sea developed in its present shape. The Arabian Sea is bounded by three different plates, i.e. Arabian, Eurasian and Indian plates (Fig. 1). Along the north western side there is convergence (Makran convergence) between the oceanic part of the Arabian plate and the continental Eurasian plate (Farhoudi and Karig, 1977; Jacob and Quittmeysr, 1979; White, 1982). In the west near the strait of Hormuz the convergence changes. The Arabian and Eurasian plates change from ocean-continent in the Gulf of Oman to continent -continent in the Persian Gulf (White and Ross, 1979). The structural feature that separates the two plates boundary is commonly called the Oman line (Lees, 1928; Falcon, 1975; Farhoudi and Karig, 1977). Toward the east, the Makran convergence zone meets in a triple junction near Karachi. In the southeast, the Murray Ridge separates the passive continental margin from the active margin of Makran. The important geological features of the Arabian Sea include the Indus Fan, the Murray Ridge, the Owen Ridge, the Owen basin, the Oman basin and the Arabian margin off Oman.

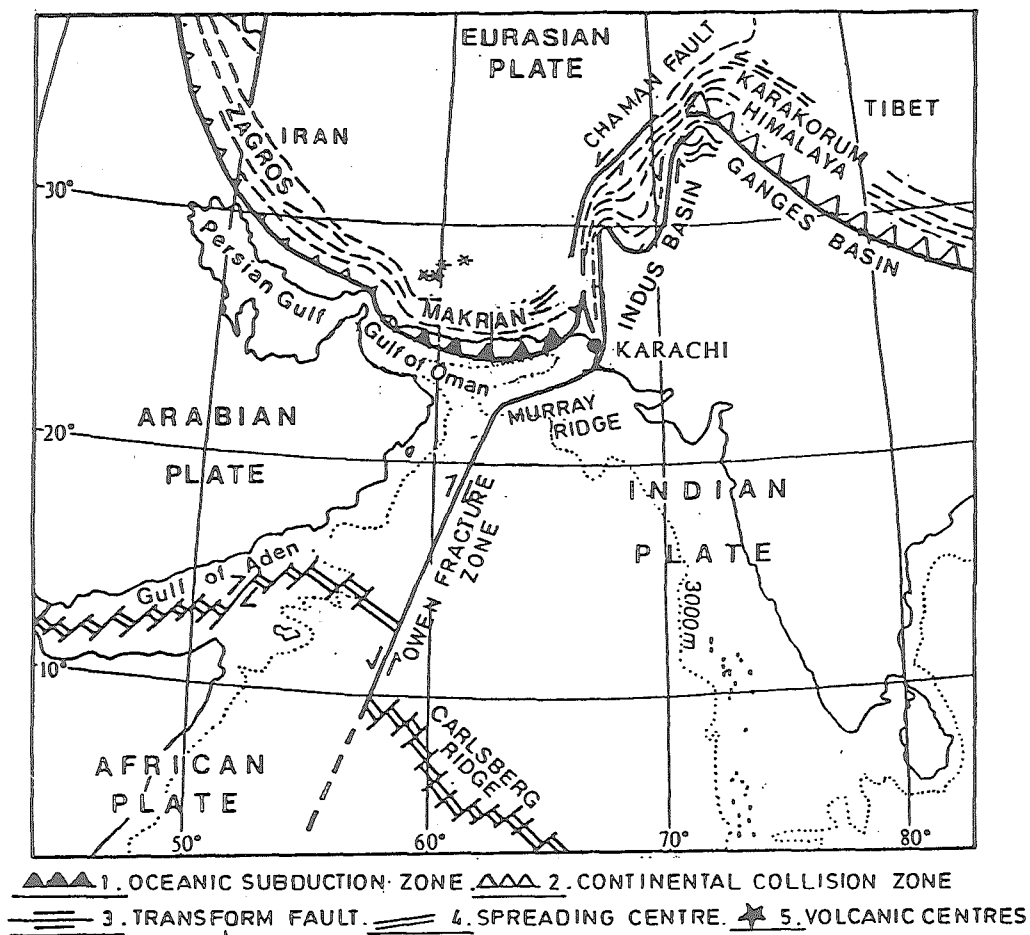


Fig. 1. Plate tectonic setting of the Arabian Sea (After Jacob and Quittmeyer, 1979)

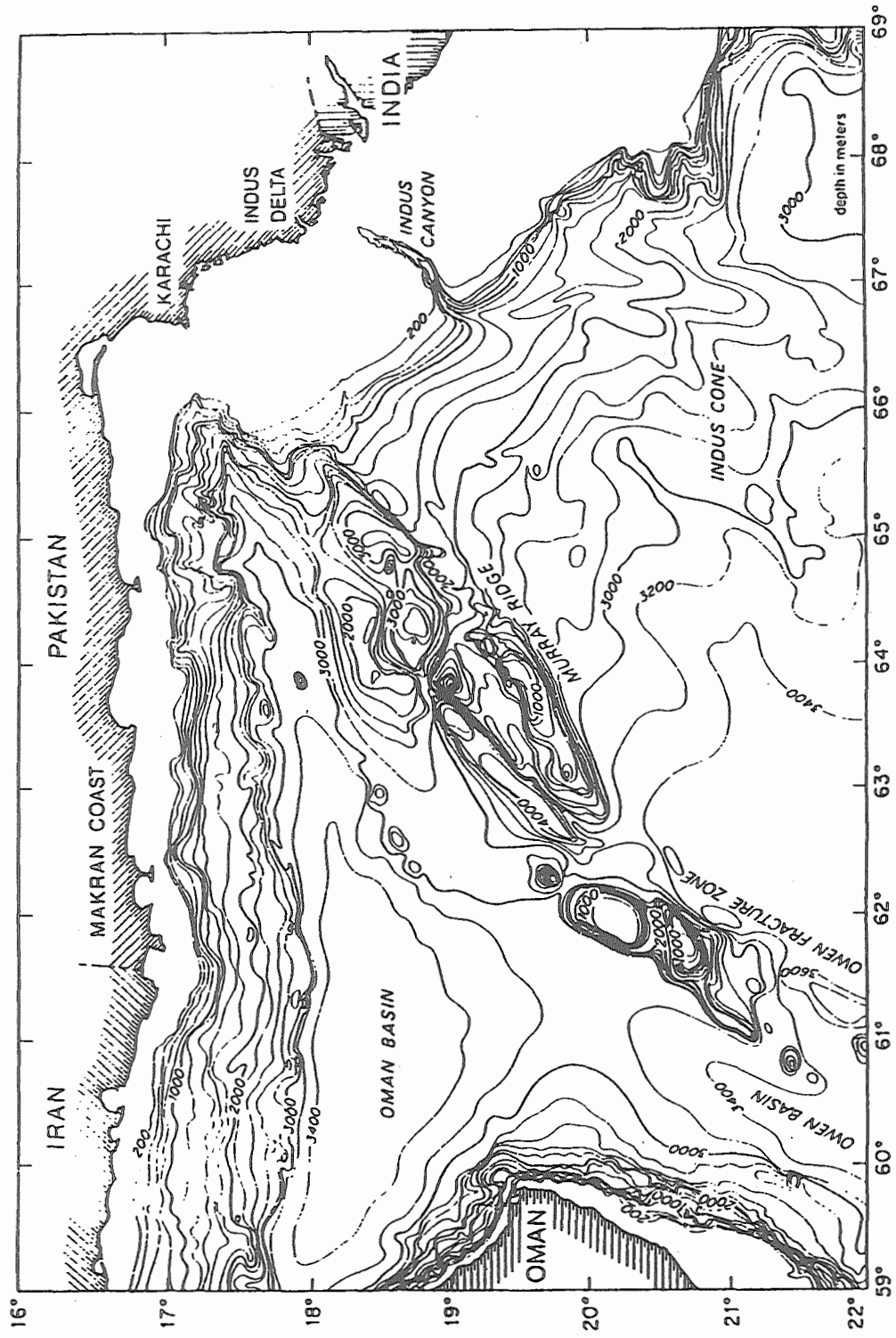


Fig. 2. Bathymetry of the Arabian Sea.

### SUBMARINE MORPHOLOGY

The bottom features of the northern Arabian Sea are shown in figure.2. An outstanding feature of the seafloor is the northeast-southwest trending graben and ridge system. This is comprised of the Owen Fracture Zone and Murray Ridge. This asymmetric ridge system divides the northern Arabian Sea into two main depositional basins: The Oman basin in the west and the Arabian basin towards the east. The Murray Ridge separates the Indus basin from the Oman basin which starts from south of Karachi and has maximum relief ranges from 1500-2000 meters. This ridge has more rugged relief in the south as compared to that of the northward relief. South of Murray Ridge is an Owen Fracture Zone. There is a ridge associated with the Owen Fracture Zone known as Owen ridge. This ridge has an asymmetric cross section. The western flank dips towards Owen basin at two degrees while the eastern flank is steep  $> 15^\circ$  drops to the Indus fan, with bare rock outcrops.

The continental shelf of the Arabian Sea shows variation in both width and depth. To the east, it has a monotonous width of about 100-150 Km. The shelf break occurs at a depth of about 100 meters off the Gulf of Kutch-Indus delta. The most pronounced bathymetric feature of the shelf-slope is the Indus canyon. This has an average width of 8 km and depth of 800 m. The canyon is 170 km long, commences around 20-30 m water depth on the shelf and ends at 1400 m depths at the continental slope. At the foot of the continental slope the canyon widens to 20 km and merges in the Indus fan. The Indus fan is the most extensive physiographic province in the Arabian Sea, covering  $1.1 \times 10^6$  km<sup>2</sup>. The continental shelf in the west is narrow and steep. Along the Makran margin the shelf width suddenly narrows to about 40 km and further decreases gradually towards the west. The continental margin off Makran illustrates striking terrace-like features. Along the Arabian coast the shelf is generally narrow. Off the Oman coast it is only about 10 km wide. The Continental slope in this area is steeper with a marked scarp southwest of Oman. The average slope of the margin is  $5^\circ$  (White, 1984).

The Oman basin is roughly triangular and occupies the central floor of the Gulf of Oman at a depth of about 3000m. The narrow elongated Persian Gulf enters the Oman abyssal plain at  $24^\circ.30$  N,  $57^\circ.40$  E. The Oman abyssal plain is connected with the Owen basin between the continental rise and Murray Ridge. The Owen basin is an elongated plain bounded by the base of the Arabian continental margin to the northwest and Owen ridge to the southeast. It is 90 to 150 km wide and 750 km long. The Red sea joins with the Arabian Sea through the Gulf of Aden at  $12^\circ$  N. The Arabian Sea basin has a maximum depth of 4500m. To the west and the northwest it abuts the Owen Fracture zone. The northwest-southwest trending Carlsberg ridge sets the southern limits of the Arabian Sea basin and separates the Arabian Sea from the eastern Somalia basin to the south (Fig. 1).

### GEOLOGY OF PAKISTAN'S EEZ (PREVIOUS WORK)

Geological information about the Pakistan EEZ is limited. Some work has been carried out in the Arabian Sea by international programs such as the International Indian

Ocean Expedition (IIOE), 1965; Deep Sea Drilling Project (DSDP), 1974; Ocean Drilling Program (ODP), 1987; Netherlands Indian Ocean Program (NIOP), 1992; Pak-German Pakistan Oxygen Minimum (PAKOMIN); 1993. Magnetic traverses were observed in the Murray Ridge area and a dredge sample was recovered from the Murray Ridge during the 1961-63 H.M.S. Darlymple cruise (Barker, 1966). During Indian Ocean Expedition in 1964-1965 little geological work was done. Gravity traverses in this area were made in 1965 and 1975 onboard the R/V Meteor and RRS Shackleton respectively. Von Stackelberg (1972) studied surface sediments. Jiapa and Kidd (1974) analyzed two DSDP cores obtained from the distal parts of the Indus cone. White (1979) interpreted the gravity and seismic reflection data collected in the Makran margin area. In the Ocean Drilling Program (ODP) Prell (1989) studied the Paleomonsoon and Geology of the north west Arabian Sea. A vast area of the northern Arabian Sea was covered recently by International cruises of the R/V Charles Darwin (1986-1988); R/V Tyro (1992) and R/V Sonne (1993). The geological investigations carried out in these programs were mainly limited to specific area and objectives.

### GEOLOGICAL FEATURES OF PAKISTAN'S EEZ

According to the Plate tectonic theory, the Pakistan continental margin has been characterized by active and passive margins. The two different types of margins are formed from two separate crustal plates. Geological and marine processes are different on these continental margins. Geologically the offshore area of Pakistan can be divided into three important zones:

- 1: Indus delta and Indus offshore basin
- 2: Active Makran subduction zone
- 3: Murray Ridge

### INDUS DELTA AND INDUS OFFSHORE BASIN

The eastern coast of Pakistan between Cap Monze and the Run of Kutch comprises the Indus deltaic region. This coast is a tectonically passive coast. Along this coast, the Indus delta and offshore Indus basin are the most significant geomorphic features (Fig. 3a and 3b). Coastal morphology shows a network of tidal creeks, small islands in the tidal channels, mud banks, swamps and lagoons (Fig. 3a). The Indus delta is among the largest deltas of the world, built by the deposition of sediments brought in by the Indus river. The nature and amount of sediment influx in the delta have varied in response to the changing geological processes and climatology in the geological past. The Indus has remained dynamic throughout its geological history by frequently changing its course. The geological history of the delta began during lower Miocene when it was formed in the Bugti area 550 km north of Karachi. During historic times i.e., 5000-6000 years B.P., the delta has prograded 150 km southward to the present position. The fan-shaped deltaic complex spreads over an area of about 30,000 sq. km. The deltaic complex is comprised of abandoned, active and subaqueous parts of the delta and river flood plains.

The geological history of the submarine Indus basin is linked with rifting of the Indian plate from the Gondwanal and opening of the Indian ocean and Himalayan

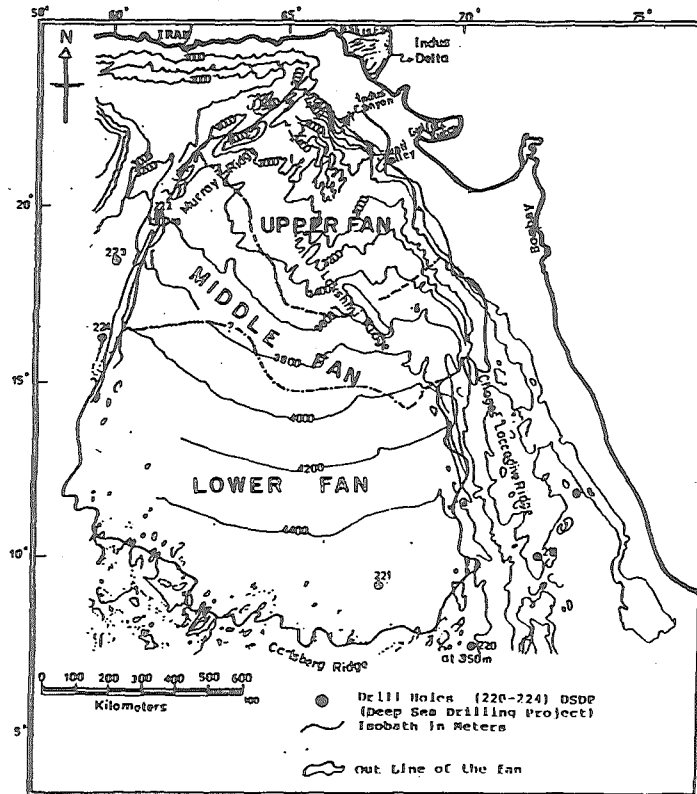


Fig. 3a. Geomorphological features of the Indus Delta. (After Wells and Coleman, 1984).

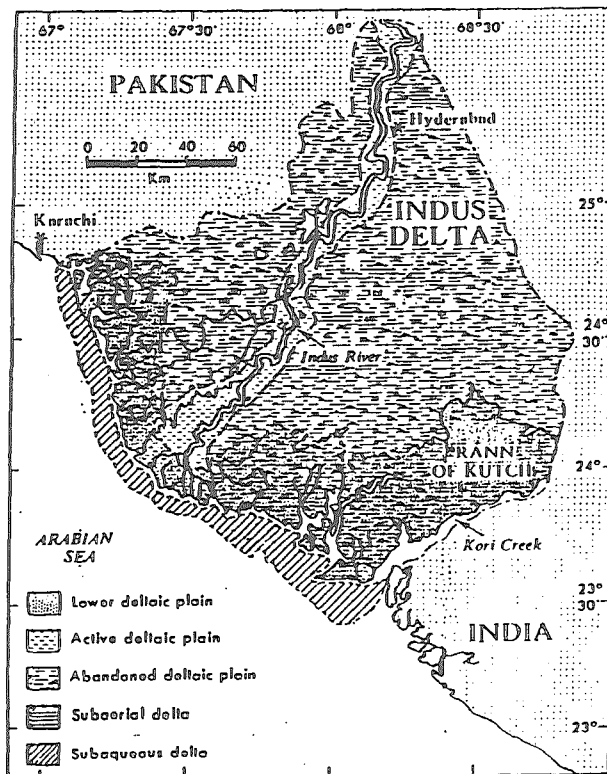


Fig. 3b. Submarine Indus Fan (After Kolla and Cumes, 1987)

tectonics. The Indus offshore basin comprises approximately 20,000 sq. km. area of the continental shelf. The shelf area consists of horst-graben complexes. Indus river through submarine canyon and leveed channels system has been supplying sediments since Miocene times. At the foot of the continental slope a large submarine fan (Fig. 3b) has been developed by the continuous deposition of sediments. The Indus submarine fan is the second largest submarine fan in the world. It extends from the Pakistan passive continental margin on the north to the Carlsberg ridge on the south. Owen-Murray ridge zone and Chagos-Laccadive ridge mark the western and eastern boundary respectively and these ridges also restrict the lateral growth of the fan. Sediments thickness is about 7 km in the Indus fan. Turbidity currents and tractive bottom currents have been the most important in transport of terrigenous material.

### MAKRAN COAST AND MAKRAN CONTINENTAL MARGIN

Geological features of the Makran coast and continental margin are shown in figure 4a and 4b. The coastline of Makran shows both erosional and depositional features. Principal geomorphic features of the Makran coast are cliffs, head land, stacks, spits, terraces, raised beaches and mud volcanoes. Rocks exposed along the coast are assemblages of sandstone, shale and mud stone deposited during Miocene, Pliocene and Pleistocene. The exposed rock sequence along the Makran coast has been divided in to:

- (1) Middle Eocene-late Oligocene rocks (Hoshab -Siahan shale and Panjgur Formation)
- (2) Early to middle Miocene sediments (Parkiani Formation)
- (3) Late Miocene-Pliocene (Talar/Hinglag Formation)
- (4) Pliocene-Pleistocene (Chatti Formation)
- (5) Early to late Pleistocene Shoreline deposits (Ormara and Jiwani Formation)

Because of seismic active the Makran coast has been experiencing minor earthquakes. Epicenters of these earthquakes occur in the Makran offshore areas. This tectonic activity has produced many mud volcanoes along the coast as a result of gas-charged water escaping to the surface. A noteworthy geological activity on the Makran coast is uplifting at rates of 1.5 to 2 mm/ year (Page *et al*, 1979; Vita-Finzi, 1979) and local normal faulting since Pleistocene time. This has resulted in beaches raised upto 500 m and several large normal faults with displacements of as much as 2000 m with extensions in offshore regions.

A number of workers have discussed the geology, morphology and tectonics of the Makran continental margin (Ahmed, 1969; Farhoudi and Karig, 1977; Jacob and Quittmeyer, 1979; Coleman, 1981; Arthurton *et al*, 1982; Harms *et al*, 1984; White, 1984). The Makran continental margin is an active subduction zone where the Arabian plate moves at a rate of 50 mm/year northward under the continental crust. The subduction zone is about 900 km long, stretching from near the Straits of Hormuz in the west to Karachi in the east. The Makran continental margin forms the seaward part of a folded accretionary prism that extends several hundred kilometer inland across the Makran. This accretionary prism, formed as the 6-7 km thick pile of sediments overlying oceanic crust beneath the gulf of Oman, is scrapped off the Arabian plate. The Makran continental margin illustrates terrace-like features (Fig. 4b). These terraces have resulted from buried ridges and basins developed by the accretion of offscraped sediments from the underlying subducting plate (White, 1982).

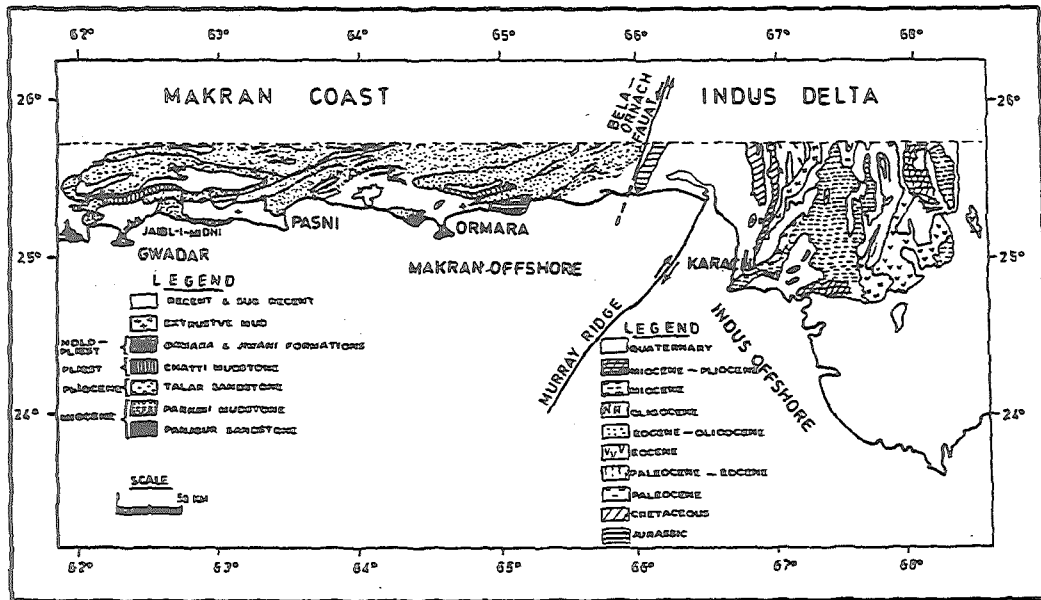


Fig. 4a. Surface geology of Makran coast, (After Crame, 1984)

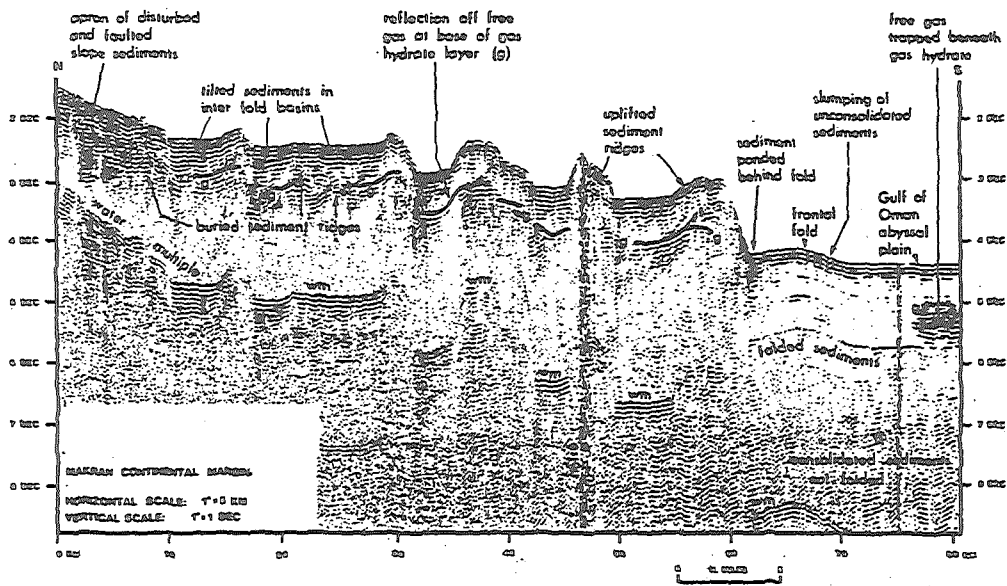


Fig. 4b. Offshore geology of the Makran continental margin (After White, 1984)



### MURRAY RIDGE

The north-east to south-west oriented Murray Ridge (Fig. 5a) is the northern continuation of the Owen fracture zone in the Arabian Sea. Limited geological and geophysical data restrict any conclusive remarks about their origin. However the strong magnetization, and dredge samples of tuff and basalt, suggest that the Murray Ridge is volcanic in origin (Baker, 1966). In pre-plate tectonic studies the Murray Ridge was treated as a branch of Carlsberg ridge extending north through the Arabian Sea.

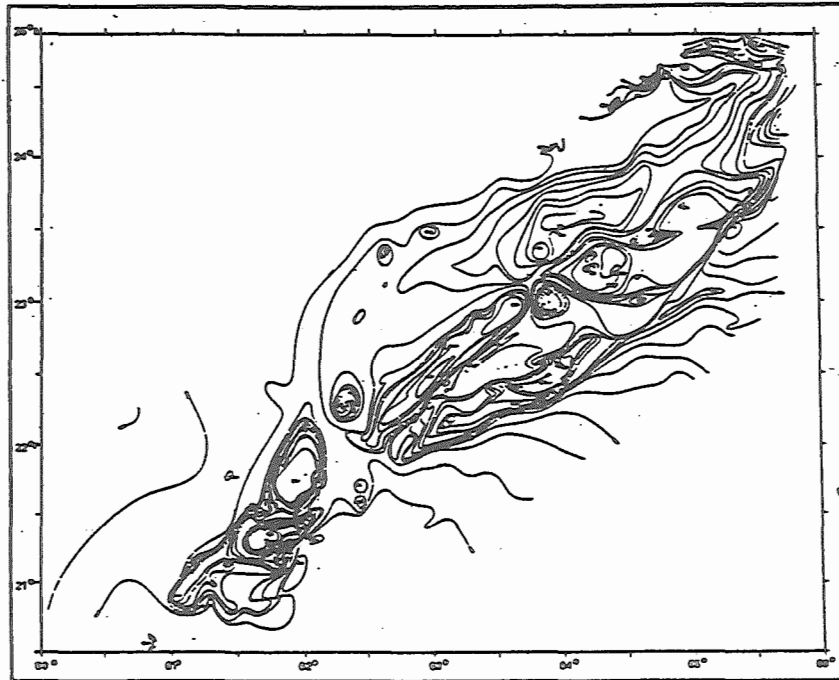


Fig. 5a. Bathymetric map of Murray Ridge (After Barker, 1966)

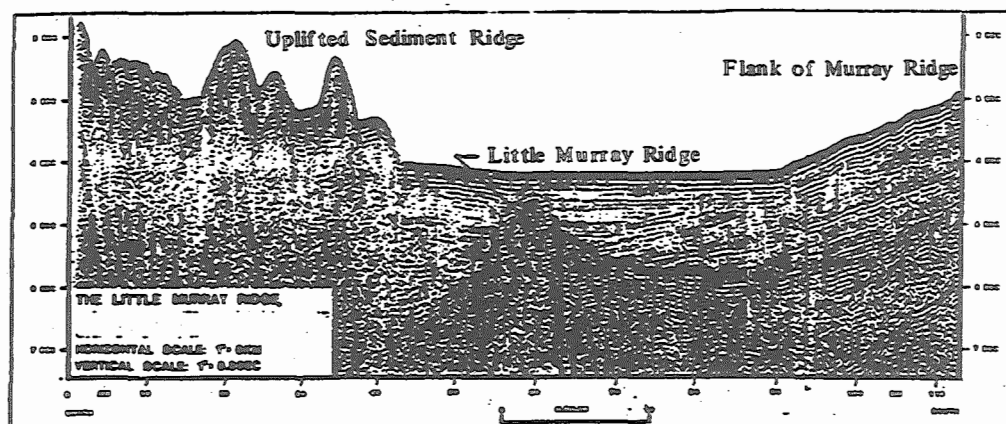


Fig. 5b. The little Murray Ridge (After White, 1983)

The northeasterly trend of the Murray Ridge and the similarity in the lithology of the dredged samples with the serpentinised and spilitic extrusive rocks of the Las Bela-Muslim geanticline suggest that the two geological features have petrological and mineralogical affinity (Ophiolitic suite). The Murray Ridge is a complex structure that may be arising from the Owen fracture complex and influenced by the Makran subduction. The Murray Ridge system is probably in the transform fault domain. It is characterized by oblique strike-slip motion, seismicity, varied sedimentation and magnetic activity. Its north-eastern end marks the triple junction between Arabian, Eurasian and Indian plates. It consists of seamounts, scarps and small basins in a linear pattern. It extends from the continental slope near Karachi over 750 km towards southwest and joins the Owen Fracture Zone. The Murray Ridge has a maximum relief of about 2000 m in the middle part and a relief as large as 3500 m in its southern part. Dredge samples in the Murray Ridge zone show tuff and variolitic or spilitic basalt fragments. West of the Murray Ridge another ridge named as the Little Murray Ridge (Fig. 5b) has been reported by White (1983). It is also a volcanic ridge and largely buried beneath sediments. In places, the basement ridge projects, forming a lineated string of seamounts.

#### MINERAL POTENTIAL

General distribution of mineral resources in the marine area is shown in figure 6. This figure supports the view that the continental margin and sea floor of the northern Arabian Sea represent all important geological features common in other oceanic regions and may have good prospects of non-living resources. The origin and nature of the geological features and processes suggest the marine geological environment is favorable for the formation of mineral resources. The continental margin and sea floor of the Arabian Sea are covered by thick sediments and may contain wide variety of mineral deposits. The climate of the land area accelerates the weathering of the source rocks in hinterland. This, coupled with run-off from rivers, favors the formation of a variety of placer deposits such as Zirconium, Rutile and Ilmenite, etc. Present oceanographic processes also suggest the formation of important economic minerals. The northern Arabian Sea sediments deposited under the upwelled water are generally rich in organic carbon >1% and known as Sapropels. These organic-rich shales are potential source rocks for hydrocarbons. Similarly the areas under the influence of upwelling and high biological productivity provide favourable depositional sites for marine Phosphorate. Concerted efforts, based on geological knowledge of offshore areas are required to exploit the sea-bed resources. New geological, geochemical and geophysical methods of prospecting, which are now commonly used for mineral exploration, can be employed effectively and usefully in locating non-living marine resources.

The basins associated with rift-graben style tectonic passive continental margin in the east are very important for hydrocarbon potential. The interaction of the fluvial and marine processes alongwith the tectonics have produced typical sedimentary facies and structures in the deltaic region. Deltaic environments are especially favourable for oil, gas, coal and heavy mineral deposits. Makran active continental margin also possess a considerable potential for accumulation of non-living marine resources. Based on the

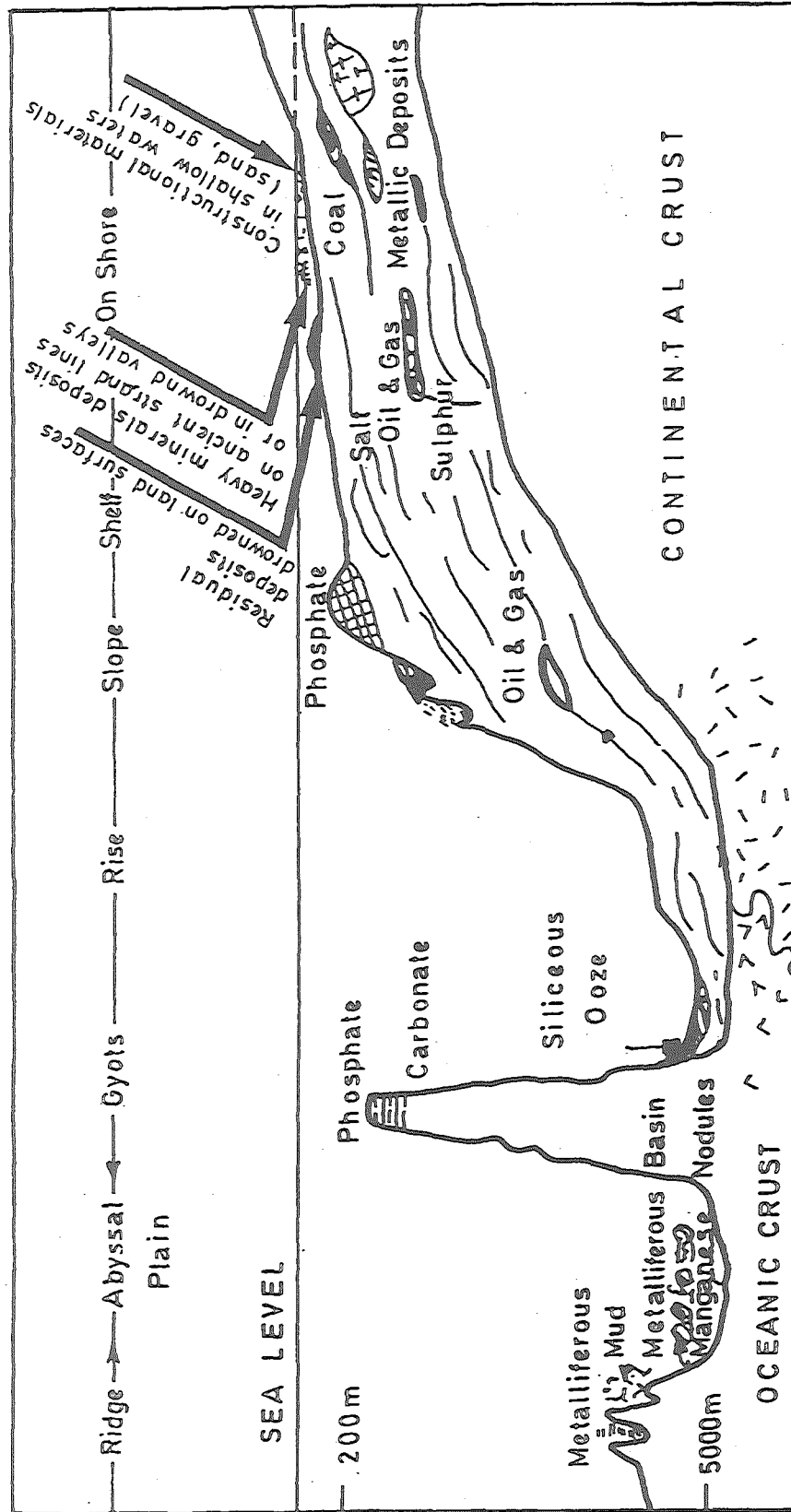


Fig. 6. Schematic distribution of minerals in ocean (After Cooks, 1975)

geological knowledge of the north Arabian Sea, the occurrence of following mineral resources in Pakistan EEZ are expected

### PHOSPHORATE

Phosphorate mineral is a raw material for fertilizer. Marine phosphorate generally occurs on the ocean floor in the form of nodules, sands, mud and consolidated beds. It is found in continental shelf and continental slope regions and may also be found on submerged plateaus and guyots. Phosphorate occurrence in marine areas is related to areas of former or recent high biological productivity. It is generally believed that marine phosphorate forms in areas of oceanic upwelling. The current oceanic processes in the north Arabian Sea suggest a potentially conducive environment for phosphorate deposition on the seafloor of the Arabian Sea particularly on the west coast. In the Arabian Sea, it is evident from the recorded data that S.W. monsoon upwellings bring nutrient rich water to the surface and induces biological productivity. These are the fundamental requirements for the deposition of marine phosphorate. The phosphorate occurrence as laminated crusts and slabs on Err seamount in north Arabian Sea has been reported (Purnachandra-Rao, *et al*, 1992). In Pakistan EEZ phosphorate nodules can be expected on the west of the Murray Ridge as have been found in other oceanic regions under similar oceanic and bathymetric settings like Chatham rise east of New Zealand. In October 1992, during the Netherlands Indian Ocean program, rocks were collected from the Murray Ridge complex, that contained phosphorate coated basalt pebbles. This suggests that phosphogenesis is occurring in Arabian Sea sediments.

From the limited geochemical studies (Khan, 1989) it can be inferred that oceanic environment is favorable for phosphorate formation. It can also be envisaged that phosphorate diagenesis may be possible during times of strong SW monsoon upwelling.

### PLACER MINERALS

Today we observe the concentration of heavy minerals by waves and currents on beaches. Deposits of coarse grained tin, chromium, titanium and tungsten-bearing placer minerals associated with coarse grained sand and gravel, all occur in shallow coastal regions. Hinterland rocks have been an important source of the placer minerals. Rivers transport large terrigenous material along with placer minerals and deposit them along beaches and shelf areas. During the last glacial stage (18000 BP) the shelf was about 100 m lower than the present depth. At that time rivers were directly emptying on the shelf and large placer minerals brought by them may have accumulated there. These minerals were dispersed and concentrated by the currents and waves during past regressions and transgressions of the coast line. Beaches and their placer minerals were shifted towards land during sea level rises. Placer mineral studies undertaken by the National Institute of Oceanography, Pakistan have shown concentration of these minerals along the coast. These deposits, located near the coast, may have submarine extensions. Hydrodynamical changes control the transport of placer minerals in coastal waters. It is most likely that strong turbidity currents and high energy conditions might have redistributed the minerals along the continental shelf off Pakistan. In depth range of up to 1000

meters Pakistan EEZ has buried basins. In these buried basins placer minerals and green sand might have been deposited during the glacial and interglacial periods. It would be very beneficial to explore the continental shelf for placer minerals, employing geological, geophysical and geochemical methods.

### BUILDING MATERIAL

In the coastal areas deposits of shells and calcareous sand have been used for construction and lime making since historical times. In shallow water, the mechanical action of waves and currents concentrates sand and gravel. These important building materials are becoming more expensive on land. In deep water, sediments contain abundant calcium and silica. In the USA and Iceland, Coquina or shell rock is mined at sea for the cement industry. Offshore sediments in Pakistan territorial waters are found rich in calcareous material composed of recent shells, and in the future may be mined for industrial use. Globogerina ooze covers a large part of the deep ocean floor and contains a very high concentration of calcium carbonate. Deep occurrence of Globogerina ooze makes its economic value questionable. With the advent of future technology the exploitation of this ooze may become economical viable. Coarse calcareous sand is a common material of the Makran continental shelf. Similarly, towards east in the Indus offshore region relict calcareous sand, with abundant broken shells, occurs at depth of >50m (Khan *et al*, 1993). Along the Makran coast, at mouths of seasonal rivers, gravel and pebbles are found. Pebbly and conglomeratic beaches occur in the adjoining areas of the Hub, Hingol and Dasht rivers. Erosion of coastal terraces by strong impounding waves are continuously supplying these building material and may have seaward extensions. It is known that Indus River has been shifting its course since geological times and has buried its many channels in the terrigenous sediments brought from the hinterland. This suggests that the present shelf has buried coarse sand, gravel, pebbles and other building materials. Therefore it is presumed that shallow marine areas could be alternate prospective areas to fulfill future requirements of construction material.

### OIL AND GAS

Offshore oil and gas bearing basins in the Arabian Sea are continuation of those on the land. The extrapolation of land trends to the continental shelf often helps in finding resources, at though there are examples when such forecasts have proved unwarranted. For instance there is no oil on land in Great Britain or Norway, but there are large offshore areas of the North sea which have been commercially exploited. In Pakistan offshore exploration for oil and gas has been very insignificant. Few wells drilled so far have shown offshore occurrences of hydrocarbons and because of technical difficulties, exploration activities have been abandoned. Offshore regions of Pakistan have thick marine sedimentary source and reservoir rocks of varying lithologies with potential traps, both structural and stratigraphic. These are positive indications of the occurrence of hydrocarbon resources in the offshore regions. The discoveries of oil fields in and around the regions also furnish positive evidence of the occurrence of hydrocarbons.

Worlds analogous of both the Makran and Indus active and passive continental margins respectively have been reported to be very rich in hydrocarbon resources. Based on a per cubic mile yield of analogous producing basins, an offshore potential of 16,650 million barrels of oil or equivalent gas has been estimated (Raza and Ahmed, 1990). All the prerequisites for oil and gas presence i.e. source, reservoir and traps are amply present in the offshore basins of Pakistan. The favorable thermal and tectonic history, and the availability of large sedimentary areas, provide hope for discovery of major and giant fields.

The Indus offshore area contains up to 9,000m of thick sedimentary rocks ranging in age from Mesozoic to Recent. In the offshore Indus basin, hydrocarbons in the Cenozoic sequence appear strong. Many seismically delineated anticlinal traps are available for exploration. Geochemical studies in the adjoining onshore area have suggested source rock potential in the Cenozoic section. Geologists have suggested that deltas, their fans, and cones are favorable locations for oil and gas accumulation. These contain buried structures and channels under the huge thickness of sediments. The deltaic basins are known to produce on average from 100,000 to 200,000 barrels of oil and gas equivalent per cubic mile. Most of the oil and gas produced in Trinidad and eastern Venezuela is from paleo delta of the Orinoco river. Similarly, major hydrocarbon accumulations have been discovered in the Oligocene to Pliocene deltaic sediments of the Mackenzie Delta and offshore Beaufort Sea in Canada. These examples lead to the conclusion that the Indus delta and Indus offshore areas may also prove hydrocarbon producing areas provided exploration activities are enhanced.

The Makran offshore area is a continuation of the coastal sedimentary region and contains thick sedimentary rocks of Paleogene to Recent age. The lithology, geometry and environment of deposition of the sediments in the Makran region also suggest that petroleum potential in the area is high. A large number of untested anticlinal structures have been seismically delineated in the Makran Offshore. The surface indication such as oil and seepages and mud volcanoes shows the generation of hydrocarbons in the area. Gas shows (mostly methane) are common along Makran (Harms *et al*, 1984). Seismic lines offshore of Makran have shown bright spots, both within the flat-lying sediments and on the cores of gentle folds, which are indicators of gas accumulation (White, 1977). Drilling in the area has been minimal, but existing data show good that quality reservoir rock may exist (Harms *et al*, 1984). Geochemical studies show that Panjgur shales and Parkiani mudstone are the best source rocks in the Makran offshore basin (Raza and Ahmed, 1990). These geological facts are to be tested by increasing the exploration activities in the area.

### METALLIC DEPOSITS

Polymetallic nodules in the Indian Ocean cover an area of  $10-15 \times 10^6$  Km<sup>2</sup> and reserves are estimated at  $1.5 \times 10^{11}$  tons. Both in terms of the area covered and estimated reserve the Indian Ocean is second to the Pacific Ocean.

Murray Ridge may prove a good environment for accumulation of polymetallic sulphide in Pakistan offshore areas. The petrology of the basalt and tuffs samples from the Murray Ridge suggest a high degree of hydrothermal alteration of the basaltic rocks

and as such the Murray Ridge zone may be a favourable area for occurrence of polymetallic sulphide. There is a strong possibility of finding because of zinc and copper-rich sulphides their affinity with the submarine hot spots. Also, manganese, crust-enriched in cobalt, sometimes occurs as a coating on basal substances such as basalt in such regions. The seamount surfaces, with a thin cover of sediments, may prove promising spots for the accumulation of both manganese and cobalt.

### SALTS

Common salt has been extracted from the ocean since ancient times. One third of the world production of salt is obtained from the sea. Seawater also contains other substances, for example, potassium chloride, magnesium, sulphate and bromine. Presently common salt is being extracted from seawater along the Sind and Makran coasts. Soda ash and other salts are also being extracted on a small scale by the traditional method of creating salt pans in enclosed water. Salt pans are successful in regions with dry hot climates where salt is evaporated through the action of solar energy. The seawater also contains important chemicals in trace amounts that can be extracted using current advanced techniques. Some of these important chemicals are uranium, bromine and iodine. The world has a great need for potassium salts. These salts are good agricultural fertilizers and are used in bleaching cloth, producing soap, etc. Seawater contains is the accurate potassium salts, and this type of extraction is more efficient than the mining of land deposits. At present potassium salts are being extracted from ocean water in England, Italy, Japan and China. In Britain and the USA, the major quantity of magnesium oxide in use is obtained from seawater.

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