FIGURE 3
Figure 3: Geology of coastal area between Mangalore and Cochin, west coast of India.
CHAPTER 3
PHYSIOGRAPHIC SETTING OF THE AREA

3.1 INTRODUCTION

The area chosen for the present studies is the shelf and slope region off Mangalore-Cochin, west coast of India in the Arabian Sea. The relevant informations regarding regional setting, bathymetry, ecology and hydrography about this area have been dealt in this Chapter, which will be helpful in arriving at meaningful conclusions. These relevant informations are extracted from various published and unpublished reports.

3.2 GEOLOGY OF THE HINTERLAND

The western Ghats constitutes the most orogenic features of the peninsular India, fringing the west coast. The distance between the scalp of the Ghats and the sea shore varies from 20–80 km.

The Tertiary and Recent formations in the coastal terrains of the study area rest directly upon the Archean crystalline complex (Figure 3). The stratigraphic succession of the area is given below in Table 4 (Aswathanarayana, 1964; Paulose and Narayanaswamy, 1968).
Table 4: Geology of the Hinterland

<table>
<thead>
<tr>
<th>Era</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recent</td>
<td>Soil and Alluvium. Beach and sand dune deposits. Lime shell deposits in back waters Older red ‘Teri’ sands</td>
</tr>
<tr>
<td>Sub-Recent</td>
<td>Sub-recent marine and estuarine formations (Marine limestone and sandy calcareous clays with shells)</td>
</tr>
<tr>
<td>Miocene to Recent</td>
<td>Residual Laterite</td>
</tr>
<tr>
<td></td>
<td><strong>UNCONFORMITY</strong></td>
</tr>
<tr>
<td>Middle Miocene to Pliocene (Warkalli beds)</td>
<td>Lateritized clayey, sandstones. Kaollinitic, limonitic to highly ferrigenous loosely packed, friable and porous sandstones, Carbonaceous clays, Grits</td>
</tr>
<tr>
<td>Middle Miocene Quilon beds</td>
<td>(Base generally marked by Gibbsitic sedimentary clays and Kaollinised Gneiss). Fossiliferous shell limestone alternating with thick beds of sandy clays, calcareous clays and sands</td>
</tr>
<tr>
<td></td>
<td><strong>UNCONFORMITY</strong></td>
</tr>
<tr>
<td>Pre-Cambrian (Archean)</td>
<td>Khondalites, Leptynites, Mica, Hornblende, younger granitic intrusions and the associated pegmatites. Charnokites and associated hybrid types of Meta-sedimentary migmatites and granitic gneisses (crystalline limestone, quartzite, various para-gneisses &amp; older granitic gneisses). Metamorphosed basic rocks</td>
</tr>
</tbody>
</table>

3.3 CLIMATE

The dominant feature of the climate is tropical monsoon which generally breaks out towards the end of May and for three to four months the whole of the western region receives heavy rainfall which is over 2500 mm (Krishnan, 1968). A seasonal heavy precipitation is carried into the Arabian Sea through numerous rivers and streams. The important rivers in the study area are Netravati, Chandragiri, Valapattanam, Ponnani and Periyar. The annual discharge of the major rivers (Rao, 1979) into the Arabian Sea are given below (Table 5).
Figure 4: Textural distribution of surface sediment (after Nair & Hashimi, 1980; Hashimi, 1990).
Table 5: Discharge of the major rivers of Mangalore-Cochin sectors into the Arabian Sea (after Rao, 1979)

<table>
<thead>
<tr>
<th>River</th>
<th>Source</th>
<th>Length (km)</th>
<th>Area (km²)</th>
<th>Average annual discharge m³x10⁶</th>
</tr>
</thead>
<tbody>
<tr>
<td>Netravati</td>
<td>Canara</td>
<td>103</td>
<td>3657</td>
<td>4,615</td>
</tr>
<tr>
<td>Ponnani</td>
<td>Anamali hills</td>
<td>251</td>
<td>5397</td>
<td>8,000</td>
</tr>
<tr>
<td>Periyar</td>
<td>Sirajni hills</td>
<td>228</td>
<td>5243</td>
<td>12,300</td>
</tr>
</tbody>
</table>

3.4 BATHYMETRY

The bathymetrical studies show that the shelf break off Mangalore-Cochin sector occurs between depth range of 90 to 120 m as described in different cruise reports of R.V. Gaveshani (Anon, 1977; 1978; 1980) and shelf width decreases from north (80 km wide) to south (65 km wide).

The shelf is relatively smooth upto 40 m water depth and beyond, it is uneven due to exposure of sands off Mangalore the shelf is marked by pinnacles rising to 2 to 3 m before shelf break. The presence of an underwater ridge was revealed with height varying from 6 to 10 m between 85 to 100 m water depth along the shelf from Kasaragod upto north of Cochin. Prominent ridges were observed at a depth of 50 m slightly north of Cochin and prominent pinnacles, ranging in height from 2 to 6 m were observed between 80 to 110 m water depth off Cochin.

3.5 SEDIMENT TEXTURE

The surficial sediment distribution of the study area is shown in Figure 4 adopted from (Nair and Hashimi, 1980; Hashimi, 1990) wherein the textural nomenclature of Shepard (1954) has been used.
Sediment texture is an important parameter in understanding the distribution of organisms in the sediments. According to Nair and Hashimi (1980), the textural distribution pattern shows three types, i.e., clayey silt, sand, and silty sand. Clayey silt forms relatively a narrow band all along the coast, continuing to < 50 m water depth and also occurs predominantly in the slope region (> 120 m depth) except for two small patches occurring off Mangalore and Azhikal. Sand covers the entire outershelf (< 50 to 120 m depth) and also occupies small areas in the upper slope region off Mangalore and Azhikal. Silty sands occur in > 40 m water depth as patches. Silty clay, sandy silt, and sand-silt-clay are the other textural types observed which are randomly distributed whose areal distribution is very limited and therefore of less significance. The sediments of the innershelf are of recent nature while those of the outershelf are relict, having radiocarbon ages between 9,000 to 11,000 years BP (Nair, 1975).

On the basis of bathymetry and sediment texture it is possible to demarcate this area into 3 regions inner shelf outer shelf and upper slope:

**Inner shelf**—This region occurs in water depth less than 50 m and is covered dominantly by clayey silts and small patch of sand in south.

**Outer shelf**—Falls within the 50 to 120 m water depth. The upper limit of 120 m is based on occurrence of shelf break. This region is almost entirely carpeted by sand.

**Upper slope**—The region occurring beyond 120 metres water depth. This region is mostly floored by clayey silts with two patches of sands i.e., one off Mangalore and another off Azhikal.
FIGURE 5
Figure 5: Dissolved oxygen in bottom waters (after Stackelberg, 1972).
Figure 6: Vertical time section of dissolved Oxygen (a) Off Mangalore (b) Off Cochin.
3.6 HYDROGRAPHY

Data regarding hydrography of near and offshore regions are available in number of research papers in scattered forms. For the present purpose data for dissolved oxygen, temperature and salinity have been taken from such reports.

3.6.1 DISSOLVED OXYGEN

Considerable amount of data is available on the dissolved oxygen content of the bottom water along the western continental margin of India (Reddy and Shankaranarayan, 1968; Sharma, 1968; Stackelberg, 1972; Rao et al., 1978; Sengupta et al., 1980). The distribution pattern of dissolved oxygen content in offshore region as given by Stackelberg (1972) is shown in Figure 5. These figures clearly indicate that the shelf waters are well oxygenated up to the depth of about 150 metres while the waters in the slope region are depleted in their dissolved oxygen content. These low oxygenated waters (< 0.5 ml/l) extend from a depth of 150 to 1,500 metres. This zone is discussed in literature as "Oxygen Minima Zone". It appears that there is seasonal latitudinal variations in oxygen content at various depths. Figure 6 (after Sharma, 1968) shows the dissolved oxygen content in the water of the continental shelf off Mangalore (Figure 6a) and Cochin (Figure 6b) regions.

3.6.2 TEMPERATURE

The sea surface temperature of the Arabian Sea has a bimodal distribution and differs from the usual pattern of a single maximum at the end of the winter. Most of the incoming solar radiations in summer is utilized in raising the water temperature and thereby developing a strong summer thermocline near surface. The maximum water temperature are recorded in May. With the advance of summer monsoon, predominant cooling takes place through (i) advection of cold water from the African coast (ii) increased heat flux to the atmosphere (iii) reduction in the
FIGURE 7
Figure 7: Average temperature variation in E.E.Z of Arabian Sea
(a) at surface (b) at subsurface (200 m depth).
(after Sarupria et al., 1988)
incoming solar radiation and (iv) entrainment of cold subsurface waters into the surface layer (Rao et al., 1976; Murthy et al., 1983; Ramesh Babu and Sastry, 1984).

Over the Arabian Sea region, surface temperature ranges from 22.5 to 28.5°C with a distinct increase from north to south. Whereas, at deeper level (500 and 1000 m) there is a decrease in temperature from north to south (Qasim, 1982). During the south-west monsoon the surface temperatures in the eastern Arabian Sea drops from 30°C in March to 27°C in August (Rao et al., 1976, Ramesh Babu et al., 1980). Murthy et al., (1983) and Ramesh Babu and Sastry (1984) have investigated the various mechanisms responsible for lowering of water temperature in the upper layers in the eastern Arabian Sea during the south-west monsoon of 1979. They concluded that this lowering of the temperature is primarily due to the downward transfer of heat which accounts to 55% of the total heat loss in the upper layers while 45% of heat is lost to the atmosphere. The water temperature increases from September onwards once again and reaches to about 29°C over most of the Arabian Sea by November and remains steady over the entire region. The surface layers once again starts cooling from December. This cooling first sets in the western and central regions while the eastern parts maintain relatively higher temperature. By January, the surface temperature reaches around 25°C north of 10°N and west of 65°E. The central and eastern regions do not cool appreciably and the temperature remains around 27°C. This cooling process ceases by February and warming starts. By May the warming is completed and the surface temperature increases to 30°C in the open sea while still higher temperatures are reported immediately off west coast of India.

Figures 7a and 7b provide the average temperature variations in surface and subsurface (200 m depth) regions off the west coast of India (Sarupria et al., 1988).
FIGURE 8
Figure 8: Annual mean sea surface salinity (°/oo) in the Arabian Sea. Contoured using 1°x 1° digital data from Levitus (1982).
FIGURE 9
Figure 9: Seasonal salinity variations (a) off Malabar and (b) off Goa (Ansari, personal communication). Section off Malabar shows two troughs coinciding with south-west and north-east monsoons.
3.6.3 Salinity

Salinity is one of the important factors controlling the distribution and ecology of recent foraminifera. The salinity variations are summarized for both Arabian Sea in general and off study area in particular. There occur two different water masses in the Arabian Sea which differ mainly in their salinity content. An excess of evaporation over precipitation promotes the formation of high salinity surface water in the central and northern Arabian Sea. These high salinity surface water contrast sharply with low salinity water along the south Indian coast and the Bay of Bengal (Figure 8). In a review of the oceanography of the northern Arabian Sea, Qasim (1982) has reported that the surface salinity in the northern Arabian Sea varies from 35.04 to 36.89/\text{oo} during June-September (south-west monsoon) and during October-January (north-east monsoon) the surface salinity varies from 35.12 to 36.74\text{/oo}. Surface salinity decreases towards south (about 34.2 to 36.2\text{/oo}). This low saline water (< 34.5\text{/oo}) in the shelf region of the south-west coast of India is attributed to the advection from south during the north-east monsoon season (Ramesh Babu et al., 1980). According to Wyrtki (1973) a strong north-east monsoon carrying low salinity water from the Bay of Bengal turns north and flows along the west coast of India, affecting the eastern Arabian Sea during the period from November to January. The mean monthly salinities at 40 and 20 m water depths of the Malabar coast (Kasturirangan, 1957) show two troughs coinciding with the south-west and north-east monsoon off the Malabar coast (Figure 9a) and whereas off Goa (Ansari—personal communication) at only one trough during the south-west monsoon period can be seen (Figure 9b).

3.7 Organic Carbon

The clayey sediments of the innershelf and upper slope are rich in organic carbon and its maximum enrichment (upto 10% occur in upper slope sediments). The average organic carbon content in the innershelf and upper slope are 1.6% and 4.11%
Figure 10: Distribution of organic carbon in Arabian Sea (after Paropkari et al., 1992).
respectively (Paropkari, 1990). The maximum enrichment of organic carbon in the entire slope region (Figure 10) is ascribed to the impingement of the oxygen minima layer (150 to 1,500 m water depth) on the floor of the slope (Stackelberg, 1972; Paropkari et al., 1992).

3.8 GEOCHEMISTRY OF THE SEDIMENTS

A detailed geochemical study of the sediments of the study area has been carried out by Paropkari (1990), wherein he has described a number of trends in the distribution pattern of different elements. The distribution profile of calcium carbonate, silicon, calcium and phosphorus show distribution pattern parallel to the coast and a general increasing trend away from the coast while the distribution pattern in case of aluminium, iron, titanium, magnesium, sodium and potassium show a reverse trend.