

CHAPTER TWO

PHYSIOGRAPHY, TECTONICS AND STRATIGRAPHY OF SINDH

GENERAL

Sindh is the second largest province of Pakistan, lying at latitudes $23^{\circ} 35'$ - $28^{\circ} 30'$ N and longitudes $66^{\circ} 42'$ - $71^{\circ} 1'$ E. It is bounded in north and west by the provinces of Baluchistan and Punjab, in east by Rajasthan (India), in south by the Runn of Cutch and the Arabian Sea (Fig. 2.1). Sindh has 240 kilometres of coastal strip in the Southwest along the Arabian Sea. It is physiographically known as the "Lower Indus Basin" which forms the southern part of Pakistan with N-S extension of about 580 km and maximum breadth of 442 kms. The province of Sindh has been sustained by River Indus for centuries. River Indus has length of 2.880 km and a third of that (about 944 kms) traverses the Sindh province. The extreme west of Sindh is generally mountainous consisting of Kohistan section of the barren Khirthar mountains. To the east is the sandy belt stretching from the borders of Bhawalpur to the Run of cutch. Between these tracts lies the Indus valley terminating in the deltaic area in the southwest. Except for the western mountainous region of Pab-Kirthar ranges and a small hilly tract in the South East corner of the Tharparkar District (Nagar Parkar), Sindh is mainly comprised of plain area (Fig. 2.1). Eastern Sindh is delimited by Rajputana desert. The Arabian

Sea forms the southern boundary of Sindh whereas it extends to the foot of the Sulaiman range in the north (Rehman, 1997).

The province of Sindh can be divided into three major physiographic divisions named as:

- 1) Western Highlands
- 2) Lower Indus valley
- 3) Desert

Western Highlands

This region includes the N-S crescent like hilly ranges of Khirthar, Pab, Laki, and Kohistan area. Rocks of these ranges consist of folded sedimentary strata that are severely folded, jointed, deeply ravined and fissured. Khirthar Range has a simple anticlinal structure with flanks gently dipping towards west and south. There is no vegetation or soil due to scanty rainfall. The highest altitude in the Khirthar range is 2072.64 meters named as Kutai-ji-Kabar i.e. Dog's grave (Pithawala, 1939).

Lower Indus Valley (Delta Area)

The lower ranges of Kohistan consist of monoclinal folds with undulatory plains in between. There is considerable subaerial denudation because of relatively high rainfall. Laki Ranges are mainly composed of Tertiary rocks and a large number of thermal springs are found here.

A large part of Sindh lies in the deltaic plain of Lower Indus valley. This region includes plains mostly overlain by alluvium, old and new, trenched with river channels in some places and overridden by raised terraces in others. A few isolated low limestone hills are the only outcrops in the plains, which are otherwise quite levelled. The Lower Indus valley may be subdivided into three parts namely (1) Western valley (2) Eastern valley and (3) Deltaic area. The western valley section is distinguished from eastern valley by the presence of old alluvium and seasonal springs flowing from Khirthar mountain into Manchar Lake (Khan, 2003).

The Deltaic area largely consists of mangrove swamps, and sandbars. The chief characteristic of the region is the changing outlets of the Indus, which act as the inlet of the sea. The deltaic area is of recent growth and is still growing. The lowland plain of Indus merges into it. The changes in the delta are caused by the mouth of the river itself and by the stormy nature of the sea during the monsoon season (Khan, 2003).

Desert

The eastern part of Sindh is covered by Thar Desert that extends into Rajputana in India. Thar desert is the 9th largest and the most densely populated desert of the world, with over 91 thousand people inhabiting in it. The origin of the Thar Desert is a controversial. Some consider it to be 4000 to 10,000 years old, whereas others state that aridity started in this region much earlier. Another theory

states that area turned to desert relatively recently, perhaps around 2000-1500 BC; around this time the Ghaggar ceased to be a major river. It now terminates in the desert. It has been observed that Late Quaternary climatic changes and neotectonics have played a significant role in modifying the drainage courses in this part and a large number of palaeo channels exist Gupta & Prakash, 1975). The name Thar is derived from Thul the general term for the region and ridges. The land area of Thar is spread over about 22,000 sq. km.

The Thar desert lies between latitudes $24^{\circ} 10'$ to $25^{\circ}45'$ N and longitude $69^{\circ} 04'$ to $71^{\circ}06'E$. It is bounded on the north by Mirpurkhas and Umerkot districts, on east by Barmer and Jaisselmir districts of India, on west by district Badin and on south by Rann of Cutch. Thar is covered by sand dunes up to an average depth of >80 meters.

Physical Features of Thar Parkar

The Thar region forms part of the bigger desert of the same name that spread over a vast area of Pakistan and India from Cholistan to Nagar Parkar in Pakistan. The Thar is mostly desert and consists of barren tracts of sand dunes covered with thorny bushes. The ridges are irregular and roughly parallel, they often enclose sheltered valleys above which they rise to a height of some forty six meters.

There are three principal landforms in the Thar desert region (i.e., the predominantly sand covered Thar, Pat or plains and Parkar). These are explained in the following section.

The desert fringe zone and aeolian sand deposits or Thar Sands: It is a barren region where sand is piled up into huge wind blown dunes. The sand dunes are of three types (i.e., longitudinal parabolic, transverse and barchans). The first type, running NNE-SSW, i.e. parallel to the prevailing winds, occurs to the south and west of the Thar. The transverse dunes, aligned across the wind direction to the east and north of Thar and barchans with the concave sides facing the wind in the interior, predominant in Central Thar. On the whole the Thar Desert slopes imperceptibly towards the Indus plain and surface unevenness is mainly due to sand dunes. The dunes in the south are higher rising sometimes to 152 m whereas in the north they are lower and rise to 16 m above the ground level (Kazmi, 1985). (Fig. 2.2).

Pat or Plains: Along the margin of the zone of longitudinal dunes, there is a relatively small zone of active and moving barchan dunes. Barchan dunes, with their two pointed crescentic ends directed northeastwards, are arranged along narrow sand ridges. Their height varies from 14 to 93 meters and the larger ones are as much as 117 to 160 meters. Southwestwards, these moving dunes are directly in contact with the longitudinal stabilized dunes. The southern margin of this zone of barchans is in the form of a straight line parallel to the margin of the Indus flood

plain. In the past, at the time of the formation of the longitudinal dunes, the southwesterly winds may have been less strong and it may be expected that there were in addition strong, relatively short cross-winds from the northwest. The northwesterly wind at present affects the northern part of the desert, but does not reach as far south as the Lower Thar Desert (Kazmi, 1985). (Fig. 2.2).

It also extends from near Nawabshah, northeastward up to Bahawalpur, and is characterized by sand dunes in the form of parallel transverse ridges. The continuity of the transverse ridges is frequently broken by the moving sand, in the form of barchan dunes or at some places in the form of small longitudinal dunes. Northeastward the dunes become more complex (Pithawala, 1946).

Parkar: The Parkar area of Nagarparkar has a rock outcrop in the center having an altitude of 400 meters which is known as Karoonjhar Hills. Hill is surrounded by plain valley of about 50,000 hectares containing alluvial deposits with granite outcrop at some places. The whole Parkar area has the alluvial deposits, the soil is fertile, having high clay and silt in it (Pithawala, 1946).

The only hills in the Thar Parkar are at Nagarparkar on the northern edge of the Rann of Kutch which belongs to Precambrian age. It consists of granitic rocks of the Aravalli range. The Aravalli series belongs to Archaen system, which constitutes the oldest rocks. The principal range of Karunjhar is 19 kilometers in length and attains a height of 305 meters (Kazmi, 1985).

The climate of Sindh is extremely hot in summer and relatively cold in winters. Drought years are common. The mean annual maximum and minimum temperatures are 35°C and 19°C, respectively. The maximum daily temperature commonly exceeds 45°C in April through June. The average annual rainfall varies between 200 and 300 mm, which occur during the monsoon season of June to September (Khan, 2003).

TECTONIC FRAMEWORK OF SINDH

In the global tectonic perspective, Pakistan is situated at the junction of three lithospheric plates, the Indian Plate, Arabian Plate and Eurasian Plate. The Indus Basin is situated on the north-western corner of the Indian Plate (Fig. 2.3).

The Indian Plate started drifting in the northeastern direction during Jurassic to Early Cretaceous time and collided with the Eurasian Plate in Paleocene to Early Eocene. During Lower to Middle Cretaceous the Lower Indus Basin was subjected to extensional tectonics and block-faulting followed by volcanic activity, as witnessed in the southern Sindh in Pakistan and Kutch region in India (Fig.2.3). The impact of collision combined with large-scale transform movement in the west is manifested in the form of fold and thrust belts and development of sub-basins (Malik et al., 1988).

Pakistan contains two sedimentary basins, the Indus basin and the Baluchistan Basin. These basins separated by a major fracture zone, the axial belt, collectively occupy an area of about 828,000 sq. km (Fig.2.4). The Indus Basin belongs to the class Extra Continental Down Warp Trough. The basin has elongated shape and is oriented in northeast-southwest direction. The main tectonic features of the Indus Basin are the platform, the foredeep comprising depressions, an inner folded zone and outer folded zone ((Memon et al., 1999).

The Platform known as Indian Platform coincides with the present Indus Plain and is sub-divided into the Punjab Monocline, Sukkur Rift Zone and Sindh monocline. The foredeep includes, from north to south, the Potwar, Kohat, Sulaiman, Sibi, Khirthar and Karachi Depressions. The Inner folded zone includes Zinda Pir, Mari-Bugti, Sanni and Mazarani, whereas the outer folded zones are Sulaiman and Khirthar Folded Zones (Fig 2.2) (Memon et al., 1999).

The province of Sindh is situated in the Lower Indus Basin and includes Sukkur Rift Zone comprising Kandhkot-Mari Horst, Panno Aqil Graben and Jacobabad – Khairpur Horst, Sindh Monocline, a part of Khirthar Depression, Karachi Depression and Mazarani Folded zone (Fig 2.5).

STRATIGRAPHY

The following stratigraphic succession, of the Lower Indus Basin has been established by various workers:

Precambrian

In Sindh Late-Proterozoic magmatic rocks of Precambrian age are found in southeastern Desert named as Nagar Parkar, that may be an extension of similar rocks in Rajasthan, India. A basement of Late Proterozoic rocks, surrounded by sandy desert at the southeastern corner of Sindh exists at latitude $24^{\circ} 22' 18''$ N. and longitude $70^{\circ} 43' 14''$ E. The Rocks of this basement are exposed at the edge of Thar Desert in the northeastern margin of Rann of Cutch (Wynne, 1967; Kazmi & Khan et al., 1973; But et al., 1994; Jan et al., 1997). Rocks of the area have been divided into three major groups, namely the Nagar Parkar igneous complex which crops out in the form of small hillocks and forms the basement; the overlying marine sedimentary rocks; and the surficial alluvial and aeolian deposits. The igneous rocks of Nagar Parkar can be classified into basement rocks, grey granite and pink granite.

The Basement rocks: The basement rocks are mainly composed of granites and amphibolites. Granites are containing xenoliths of basic rocks, both of plutonic and volcanic origin.

Grey Granite: The grey granite is the main variety of the area. It occurs in Karunjhar and forms the largest outcrop of plutonic igneous rocks of granitic composition (Butt et al., 1994; Muslim et al., 1997). The Grey granites are the second oldest rocks in the complex after the amphibolites (Jan et al., 1997).

Pink Granite: The outcrops of the pink granites are best seen along the northeastern margin of the Karunjhar hill directly below the grey granite. The largest body of this granite is characterized by a typical pink colour (Kazmi & Jan, 1997).

The rocks are generally medium- to coarse and fine-grained. There are several acidic dykes exposed in this area, the fine-grained granite is greyish pink in color. The rocks may be a part of the basement rocks, as they also occur as xenoliths in the coarse-grained granite (Jan et al., 1997).

Jurassic

The Jurassic sedimentary rocks largely constitute a thick (820m-3000m) sequence of marine pericratonic shelf deposits consisting of limestone, shale, and sandstone with subordinate dolomite and ferruginous beds. They form a platform cover in the entire Indus basin/area (Kazmi & Jan, 1997).

Cretaceous

The Cretaceous sediments belonging to Lower Indus Basin (particularly Sindh) which has various lithology ranging from shale deposited in deep depressions which in turn are overlain by shallow marine limestones and thick sandstones in the upper part. Cretaceous sedimentary rocks are exposed in the Kirthar region of the lower Indus Basin. Except for local disconformities there is a complete sequence of the upper cretaceous rocks ranging from Maestrichtian. The sequence comprises vast amount of fossiliferous shale, carbonates and clastic sediments Pab sandstone (Farshori, 1972).

i. Mughal Kot Formation: The term Mughal kot Formation has been applied to the rocks developed between the Parh limestone and Pab sandstone on the border of Baluchistan (Sulaiman Range) and Sindh (Williams, 1959). This Formation largely consists of grey, silty, calcareous shale in the Kirthar area. In Sindh near Dhabbo creek, basalt has been found in this Formation. The basal part of the Mughal Kot Formation exposed at the Bara Nala section is creamy in colour, hard, compact, fossiliferous, and crystalline. In most of the areas, the Mughal Kot Formation overlies the Parh Limestone unconformably but in Karachi a conformable contact has been observed by Fatmi (1977). On the basis of *Omphalocyclus* sp., *Orbitoides* sp. Campanian, Early Maestrichtian age has been assigned to this Formation (Williams, 1959; Marks, 1962).

ii. Pab Sandstone: Vredenburg (1909) and Williams (1959) named this formation as Pab sandstone. It is exposed in the Kirthar region, resting conformably on the Fort Munro Formation, but in some localities overlies Parh limestone unconformably (Shah, 1987). It consists mainly of white, cream or brown thick bedded to massive cross-bedded, medium-coarse-grained quartzose sandstone, with intercalations of subordinate argillaceous limestone and shale. The type section is west of Wirahab Nai in Pab Range, and its thickness ranges from 240 m (Mughal kot) to 1000 m in Pab Range (Kazmi & Jan, 1997). The Pab sandstone at places is unconformably overlain by Paleocene Khadro Formation (Fatmi, 1977). On the basis of Maestrichtian foraminifera, the Pab sandstone has been assigned a Late Cretaceous age (Vredenburg, 1909).

Cenozoic/ Paleocene

Ranikot Group: In the Kirthar area of the Indus Basin, the Paleocene succession consists of the Rani kot Group (Blandford, 1876; 1879, Vredenburg, 1909). This group has a basal marine sequence of sandstone and shale with interbeds of limestone and basaltic lava flows (Khadro Formation), a middle fluvial to paralic sequence of sandstone and shale with coal and carbonaceous beds (Bara Formation), and an upper sequence consisting of marine limestone and some estuarine sandstone and shale (Lakhra Formation).

Khadro Formation: Khadro Formation is widely distributed in the Kirthar and adjacent region. It lies unconformably on the Late cretaceous Pab sandstone. At the type locality (Bara Nai in the Laki Range), the basal part of the Formation consists of limestone containing oysters and reptile bones. This is followed by a series of olive-grey to brown gypsiferous medium grained fossiliferous limestone. A number of basaltic lava flows are also present in it. The thickness of the Formation is 140m as revealed by a test hole at Lakhra coalfield (Williams, 1959). Fossils in Khadro Formation include *Cardita beaumonti* (Blanford, 1878), *Globigerina pseudobulloides* and *G. triloculinoids* (Nagappa, 1959). The Formation has thus been considered to be Early Paleocene in age.

Bara Formation: This Formation conformably overlies the Khadro Formation and is widely distributed in the Kirthar Range and adjacent areas. The type section is in Bara Nai in Laki Range and adjacent areas. The Formation consists of interbedded sandstone and shale. The sandstone is fine to coarse grained, calcareous, ferruginous and at places glauconitic, ripple marked and cross-bedded. Beds range in thickness from a few centimeters to 3 m (Kazmi & Jan, 1997). The shale is soft, earthy, gypsiferous and commonly carbonaceous. Oyster shale, some reptile remains and abundant leaf impressions have been found. *Ostraea Talpur* has been reported from the base (Vredenburg, 1909). The Formation has been given Middle Paleocene age (Cheema, 1977).

Lakhra Formation: Lakhra Formation overlies the Bara Formation and crops out in the Kirthar and adjacent areas. The type section is southern part of the Lakhra anticline (Cheema et al., 1977). It consists mostly of grey, thin to thick bedded, nodular, sandy, and in places argillaceous, fossiliferous limestone, with interbeds of sandstone, shale in the upper part. Its thickness ranges from 50 m to about 242 m (Kazmi & Jan, 1997). The Formation contains rock assemblage of foraminifera. On the basis of Corals, mollusks, *Miscellanea miscella*, *M. stampi*, *Lockhartia haimei*, *Lepidocyclina* etc. and echnoids. Late Paleocene age has been assigned to the Lakhra Formation (Davies, 1926; Nuttal, 1931; Duncan, 1881; Vredenburg, 1909, 1928; Duncan, 1835; Cheema et al., 1977).

Laki Formation: The term Laki Formation has been proposed by Hunting Survey Corporation (HSC) (1960). It overlies the Ranikot Group unconformably and is exposed mainly in the southern Kirthar Range. The type locality is near Meting and near Mari Nai in the northern Laki Range. The Formation comprises cream coloured to grey limestone, with subordinate marl, calcareous shale, sandstone and lateritic clay. It contains a rich fossil assemblage of foraminafera, gastropods, bivalves, echinoderms and algae. The lower part of the Formation has been divided into the Sonhari Member and Meting limestone and Shale member by HSC (1960). The Sonhari Member contains lateritic clay, shale, pockets of limonite and ochre, coal beds, sandstone and locally developed yellow, arenaceous limestone. The Sonhari Member is overlain by Meting limestone and Shale Member (Vredenburg 1906), which consists of thin-bedded creamy white, fossiliferous, nodular

limestone followed by a sequence of interbedded limestone and shale with subordinate sandstone. The age of the Laki Formation is Early Eocene (Noetling, 1903; HSC 1960).

Sonhari Formation: The Sonhari Member of HSC (1960) has been excluded from the Laki and renamed as Sonhari Formation because it is distinct from the overlying Laki and Lakhra limestone and it comprises a distinct non-marine to brackish water deposits (Outerbridge et al., 1989).

Tiyon Formation: The term Tiyon Formation has been proposed by HSC (1959), to the upper beds of Late Lower Eocene in Sindh. These rocks were included by Vredenburg (1909) with Kirthar Series. The type section is exposed along the Tiyon Nai. (Lat. 26° 8' 30" E, 67° 7' 15") south of Manchar Lake. The Formation mainly consists of shale, marl, and limestone. The shale is bluish green, greenish brown, yellowish grey in colour and is calcareous and gypsiferous. The marl is gently nodular, and weathers yellow, reddish brown and cream white. The limestone is thin bedded, nodular and marly, it is cream in colour and contains ferruginous nodules. The Formation is highly fossiliferous containing foraminifera. Generally Tiyon Formation is exposed on the western flank of Laki range and can be found at Thano Bula Khan, Kalu Kuhar and west of Bara nala. It is exposed near Kotdijji and Rohri, where it is underlying Kirthar limestone. It is absent on the east of Laki range. The Tiyon Formation is conformable with underlying Laki Formation and overlying Kirthar Formation. The Formation has been deposited in

shallow marine environment on the shelf. *Alveolina oblonga*, *Ovicula*, *Ovoidea*, *Assiilina exponens* fossils are found in this Formation, indicating an age of Late Ypresian to Early Lutetian (Farshori, 1972).

Kirthar Formation: Kirthar Formation overlies the Laki Formation conformably in Kirthar area. The type area is in the Kithar Range (Gaj River section) (Blandford, 1876; Noetling, 1903). The Formation is mainly fossiliferous limestone interbedded with subordinate shale and marl. The limestone is thick-bedded to massive, nodular in some areas, grey to white in colour and locally contains algal and coralline structures. In some localities the upper half of the Formation is massive cliff-forming limestone. The shale is olive orange, yellow or grey, soft, earthy and calcareous. The thickness of the Formation ranges from 15m to 30m in western Kirthar Range and in Gaj River type section it is 1270 m thick (Cheema et al., 1977). The Formation contains abundant foraminifera, gastropods, bivalves, echinoids and vertebrate remains. The age of Kirthar Formation is Middle Eocene to Early Oligocene. (Oldham, 1890; Vredenburg, 1906, 1909; Pilgrim, 1940; Eames, 1952; HSC, 1960).

Nari Formation: Nari Formation is exposed extensively in the Kirthar region as scattered outcrops. In Kirthar province it conformably overlies the Kirthar Formation except in Hyderabad anticlinorium where it oversteps and unconformably overlies the Kirthar and Laki Formations (Blandford, 1876; Williams, 1959). The type section is in the Gaj river gorge in the Kirthar Range

(Kazmi & Jan, 1997). The upper part of the Nari Formation is mostly brown, fine to coarse-grained sandstone with interbeds of shale. The lower part consists of interbedded grey to brown, fossiliferous sandy limestone, calcareous sandstone and shale. At many places/localities the lower part of the Formation is gray to brown shelly, nodular, thick-bedded to massive limestone, which has been named as the Nal Member (HSC, 1960). The thickness of Nari Formation ranges from 1045 m to 1820m in the Kirthar area. It contains a rich fauna including echinoids, mollusks, corals, foraminifera and algae. Some of the significant large foraminifera include *unmulites intermedius*, *N. Vascus*, *. fichte*, *N. Clipens* and *Lepidocyclina dilatata* (Duncan et al., 1834; Khan, 1968; Iqbal, 1969). The age of the Nari Formation is Oligocene to Early Miocene (Latif, 1964; Khan, 1968).

Neogene

Gaj Formation: In the Kirthar Range, the lower part of the Neogene consists of near shore marine to estuarine sediments of the Gaj Formation. The type locality is at the Gaj River (Blanford, 1876; Williams, 1959; Pascoe, 1964; Cheema et al., 1977). The Formation rests conformably and transitionally over the Nari Formation (Kazmi & Jan, 1997). The Gaj Formation is mostly shale, which is variegated, grey and gypsiferous and cross-bedded sandstone and fossiliferous brownish, argillaceous limestone. However, in the southern part of the Kirthar range in the Kirthar area, the Formation predominantly consists of yellowish brown sandstone and cream coloured or pinkish white argillaceous limestone. Its maximum

thickness is about 600m in the Kirthar area. The Formation contains foraminifera, mollusks, echinoids and corals (Nuttall 1931; Vredenburg 1906, Hunting Survey Corporation 1960; Khan 1968; Cheema et al., 1977). The Gaj Formation is Early Miocene (Aquitainian to Burdigalian) in age but in places may extend into Middle Miocene (Pascoe, 1964; Khan, 1968).

Siwalik Group: In the Kirthar range, the Gaj Formation is overlain by the Siwalik Group, which is composed of molasse type sediments. It overlies the Gaj Formation conformably (Middlecott, 1864; Pilgrim, 1913; Lewis, 1937; Cheema et al., 1977). The term Siwalik group now includes the Manchar series of Blanford (1876) and Vredenburg (1906). Manchar Formation was named after the Manchar Lake (Lat. 26° 08' N, Long. 67° 34' E) It is chiefly composed of sandstone, shale, clay and subordinate conglomerate and is well developed in Sindh. It occupies large area of Laki Range particularly in the synclinal valley in the north and west of Laki Range. In the Gaj river section the contact between the Manchar Formation and underlying Gaj Formation is gradational/transitional drawn above the gypsum bed. Near Manchar Lake and east of Laki Range, i.e. Bara Nala, Ranikot, Laki shah Saddar and Sehwan the lower contact is disconformable. In most of the areas the formation is overlain by Recent to subrecent deposits. The Siwalik Group consists of (a) Nagri Formation (b) Dhok Pathan Formation (Kazmi & Jan, 1997).

Nagri Formation: The type locality of Nagri Formation is Nagri village at Gaj River. This Formation overlies the Gaj Formation in the Kirthar Range. At some places an angular unconformity may be observed (Cheema et al., 1977). The

Formation is largely thick bedded to massive, greenish grey, medium to coarse grained calcareous sandstone, interbedded with subordinate brown to reddish sandy clay and conglomerate. The Formation has yielded a rich vertebrate fauna including proboscideans, rhinocerotides, crocodiles, chelonians and aniodactyles. The age of Nagri Formation is Early Pliocene/Pontian (Pilgrim, 1913; 1926; Lewis, 1937; Cheema et al., 1977).

Dhok Pathan Formation: The type section of Dhok Pathan Formation is at Dhok Pathan village. It has transitional contact with the underlying Nagri Formation and consists of thick pile of interbedded sandstone and clay. The sandstone is thick-bedded, grey to brown, calcareous and cross-bedded; the clay is brown, orange to red. Lenses of conglomerate are present in the upper part (Blanford, 1876; Griesbach, 1893; Pilgrim, 1913; Cheema et al., 1977). It is less fossiliferous in the Kirthar Ranges. However, *Hipperion punjabiense*, *Rhinoceros sivalensis* and *Pachyportax latidens* have been found (Cheema et al., 1977). The age of the Formation is Early to Middle Pliocene (Kazmi & Jan, 1997).

Quaternary

Quaternary stratigraphic sequence in Sindh represents marine, coastal deposits, shore and offshore deposits, the aeolian deposits of the Thar, evaporates of Salt lakes and flood plain and delta of the Indus River. The Thar Desert along the eastern margin of Indus plain, is largely covered with longitudinal and complex seif type established sand dunes. Some of the longitudinal sand dune ridges have a

relief of as much as 100 m and are more than 40 km long (Kazmi, 1977; 1985). The aeolian deposits of Thar Desert range in age from Pleistocene to Recent.

Lei/Dada Conglomerate: In the Kirthar foredeep on the western side of the Lower Indus plain, the Lei conglomerate (Dada conglomerate of Hunting Survey Corporation, 1960) overlies Siwalik Group and earlier formations with a sharp angular unconformity (Gill, 1952). It is composed of thick beds of boulder, conglomerate and subordinate coarse, cross-bedded sandstone. This may be piedmont out wash deposit in the foothill region and in the piedmont plain; it is overlain by younger unconsolidated piedmont deposits. Towards the Indus plain it interfingers with silt and clays of Larkana Formation. Lei/Dada conglomerate is unfossiliferous and its age has been inferred as Early to Middle glaciation (Kazmi, 1984).

Nabisar Formation: South of Nawabshah, a subsurface sequence of more than 125m thick deltaic hard clay, interbedded with lenses of very fine sand, overlies the Eocene bed-rock and Siwaliks (Manchar Formation of Blanford, 1876). The clay is laminated and ranges in colour from dark grey, brown to greyish white. It is calcareous and at places contains abundant mollusc shells, resembling the deltaic deposits. The oil wells at Nabisar, and other ground water test holes in Mirpur Khas and Nabisar and farther northwards, encountered a thick sequence of this Formation, which has been named after the town of Nabisar. This deep inland position of deltaic deposits is due to the rise in sea level and consequent inland

encroachment of delta during the last and earlier interglacial stages (Kazmi & Jan, 1984).

Larkana Formation: The name Larkana Formation has been proposed by Kazmi (1966, 1974) and Kazmi and Jan (1997), It is composed of siltstone and clay with interbeds of very fine sand ranging in thickness from 20 m to more than 120 m. The Formation has been encountered in boreholes upstream of Sehwan. Near Khairpur it overlies the Eocene limestone, where as west of the Indus it interfingers and correlates with the Lei/Dada conglomerate and is overlain by piedmont deposits that were interpreted as an ancient sub piedmont deposit and correlated with the lie/Dada conglomerate. Its age varies from Early Middle to Late Middle glacial periods (Kazmi, 1966).

Tando Jam Formation: The term Tando Jam formation has been proposed by Kazmi (1966), Kazmi and Jan (1997), for the coarse sand of channel to the lower Indus Plain at the depth of 130-200 m depths and about 50 km wide buried channel of Indus. The channel is filled with very fine to coarse sand with pebbles and cobbles. The sand has been named as Tando Jam where the Formation was first recognised and is well developed. This Formation is comprised of an upper fine sand member of ~70m of uniformly deposited fine to very fine sand similar to the sand presently deposited by the Indus.

The lower gravelly coarse sand member occurs below the depth of 80 m and is largely comprised of medium to coarse-sand with pebbles and large cobbles.

The faceted pebbles and cobbles indicate a cold glacial regime during ice rafting. In the eastern part of the lower Indus plain, the Tando Jam Formation overlies Nabisar and Larkana Formation. In the western part it overlies the Larkana Formation and the piedmont and sub-piedmont deposits. The age of lower member of the Tando Jam Formation is Early Holocene and the upper member of this formation is Late Holocene (Kazmi & Jan, 1997).

Table 2.1. Stratigraphic succession of Sindh (after Farshori, 1972 and Kazmi and Jan., 1997).

AGE	FORMATION/GROUP	THICKNESS (IN METERS)
Quaternary	Tando Jam Formation	130m-200m?
	Larkana Formation	20m-120m
	Nabisar Formation	125 m
	Lie/Dada conglomerate	?
Upper Miocene to Pliocene	Siwalik Group { Dhok Pathan Formation Nagri Formation	1330-2000m
		200m -3000m
Lower to Middle Miocene	Gaj Formation	600 m
D i s c o n f o r m i t y		
Oligocene	Nari Formation	1045-1820m
D i s c o n f o r m i t y		
Eocene	Kirthar Formation	15m- 270m
	Tiyon Formation	350-500 ??
	Laki Formation	40m-100 m
D i s c o n f o r m i t y		
Paleocene	Ranikot Group { Lakhra Formation Bara Formation	50 m -242m
		3 m
Paleocene	Khadro Formation	67m-180 m
D i s c o n f o r m i t y		
Upper Cretaceous	Pab Sandstone	240m-1000m
	Mughal kot Formation	150m-170m
Precambrian	Nagar Parkar igneous complex	

SINDH PHYSIOGRAPHIC DIVISIONS

Scale
1:940000 (1 cm = 19.4 Km)


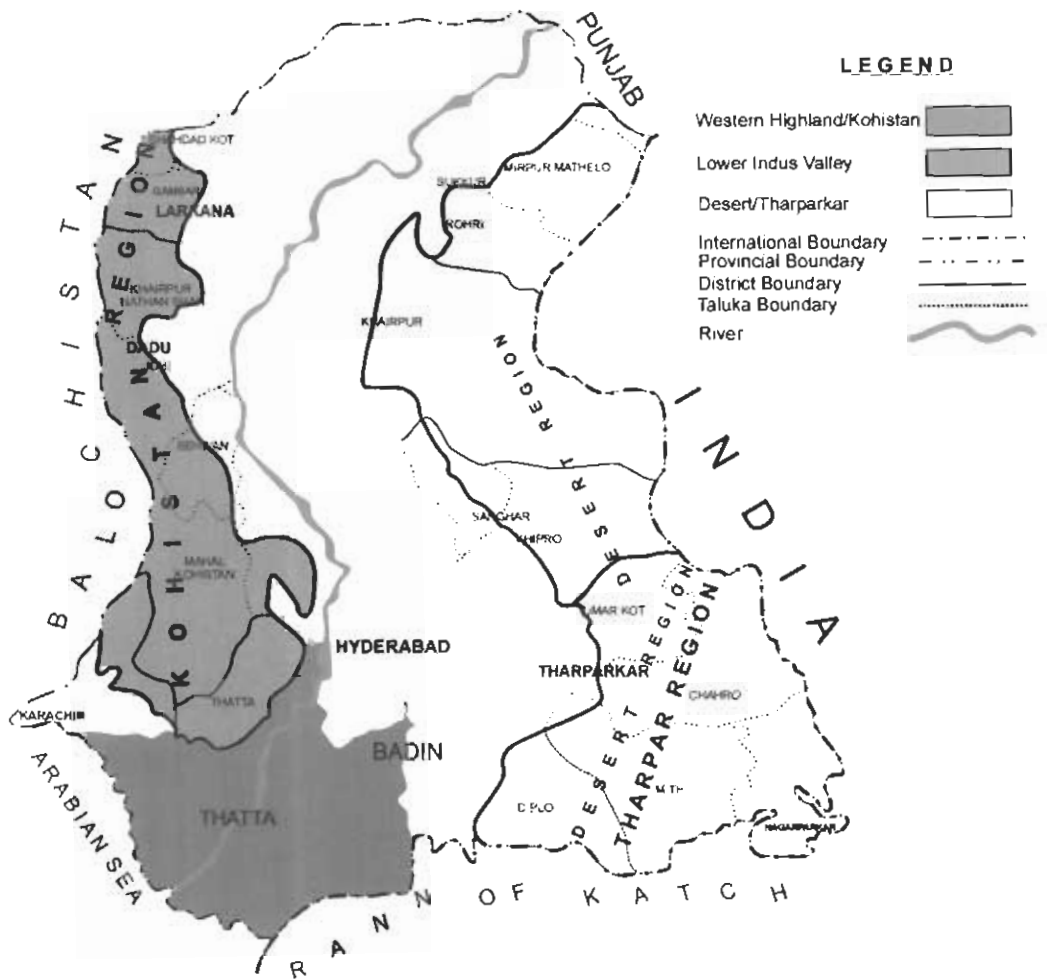



Fig. 2.1 Map showing physiographic divisions of Sindh province, Pakistan.

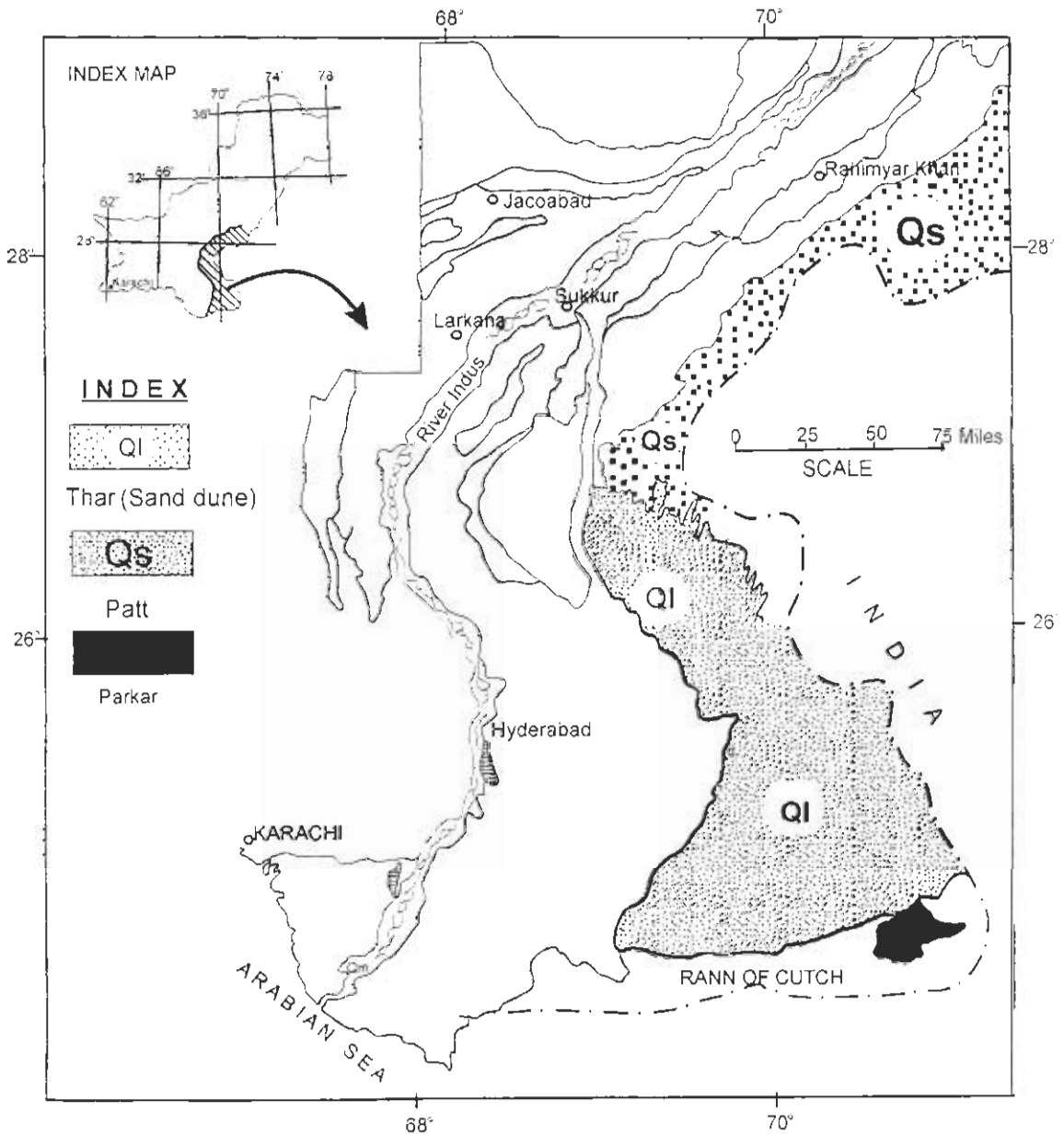


Fig. 2.2 Map showing Physiographic divisions of Thar desert, Sindh province, Pakistan (after Kazmi, 1985).

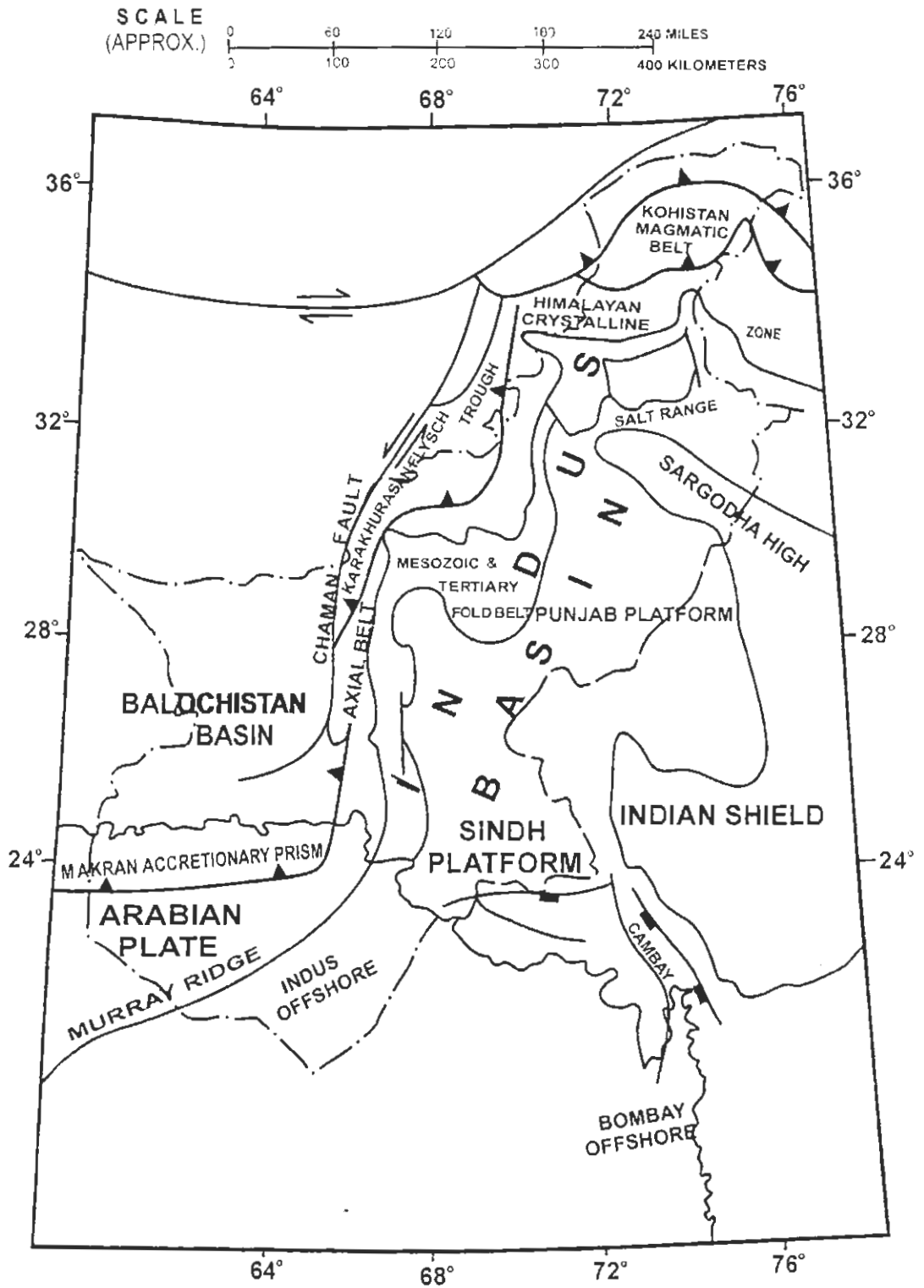


Fig 2.3 Map showing tectonic divisions of Pakistan, and sedimentary basins of Pakistan (Raza et al., 1989).

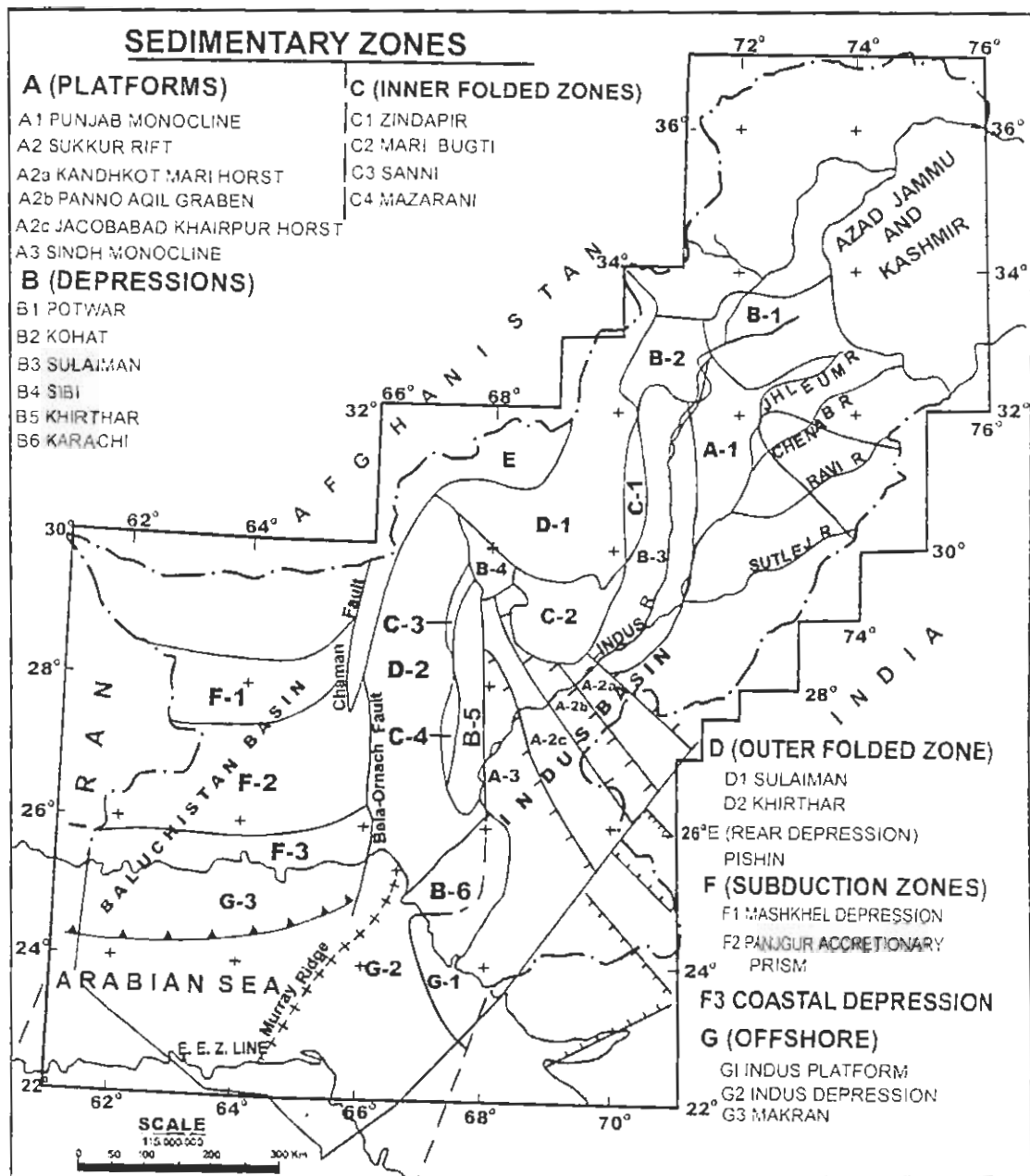


Fig. 2.4 Map showing details of Sedimentary Zones of Pakistan (after Raza et al., 1989).

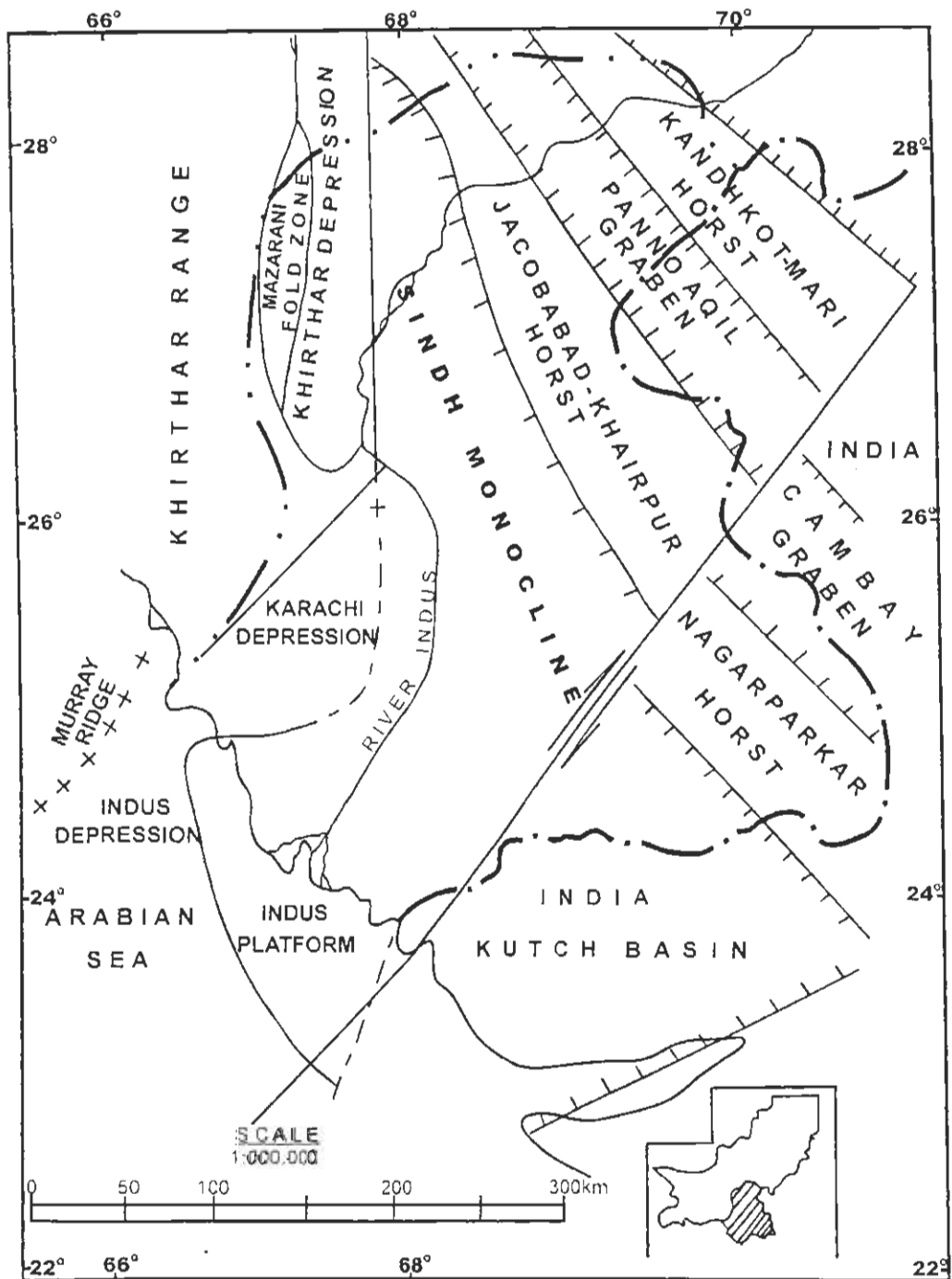


Fig. 2.5 Map showing Tectonic Map of Lower Indus Basin, Sindh province, Pakistan (after Raza 1989).