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PETROLEUM ZONES OF PAKISTAN

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Abstract

In Pakistan, the early exploration approach of merely searching for favourable locations within sedimentary basins has been replaced in recent years by a comprehensive and scientific basin analysis aimed at understanding why, when and how petroleum occurs in a basin. In this study we introduce our sedimentary basins and delineate 24 possible petroleum zones within 7 main tectonic features of these basins. Potential plays in each petroleum zone are also indicated.

Introduction

Pakistan occupies a total onshore and offshore sedimentary area of about 828,800 sq km with an estimated sedimentary volume of 3,791,060 cubic km. It represents the most extensive active collision region in the world. Its sedimentary exposures and geological structures have attracted geologists for over hundred years. Petroleum exploration in Pakistan is 120 years old and the first commercial discovery dates back to 1914. The regional tectonics and geology of the country have been discussed by Wynne (1875 & 1878), Oldham (1890), Vredenburg (1906), Gill (1952), Pinfold (1953), Wadia (1957), Williams (1959), Krishnan (1960), Hunting Survey Corporation (1961), Zuberi & Dubois (1962), Rahman (1963), Bakr & Jackson (1964), Sokolov & Shah (1966), Voskresensky, Kravchenko & Sokolov (1968), Stocklin (1977), Shah (1977), Farah & Dejong (1979), White (1979), Gansser (1981), Kazmi & Rana (1982), Raza & Alam (1983), Raza (1985), Khan, Ahmed, Raza and Kemal (1986), and Khan & Raza (1986).

The present paper describing petroleum zones of Pakistan was prepared on the basis of the above mentioned works and is the first in a series of reports compiled by the Hydrocarbon Development Institute of Pakistan (HDIP) for the project "Review of Petroleum Exploration Data and Evaluation of Sedimentary Basins of Pakistan".

Geological Setting

The crust of Pakistan contains two large sedimentary basins: Indus in the east and Baluchistan in the west (Figure 1). A major fracture zone comprising Chaman and Bela-Ornach fault systems, with ophiolitic melange, separates the two basins. The Indus basin is developed on the Indian plate which collided with the Eurasian plate during the Tertiary. The Baluchistan basin is formed between a buried trench and a magmatic arc as a result of active subduction of the Arabian plate beneath a block of the Eurasian plate.

Description of Petroleum Zones

Indus Basin

The Indus basin falls in the Type IV (Intermediate Crustal type): Extracontinental Downwarps toward Oceanic Areas of Klemme (1970) and Extracontinental Trough Downwarp of Riva (1983). Such basins produce from 4,800 to 7,200 barrels of oil or equivalent gas per cubic kilometer of sediment, and also contain giant fields. Analogues are found in North Africa, Romania, Central Europe, Italy and South Asia. The Indus has an area of 533,540 sq km with an average of 4.8 km thick sedimentary section. The sedimentary rocks in the basin range in age from Late Precambrian to Recent and are predominantly of marine origin (Figures 2-5). A large number of oil and gas seepages/shows occur in exposed sections and wells (Figure 6). Sixty three oil and gas fields have been discovered as of January 1989 which include two giant gas fields (Table 1). The producing horizons are sandstones of Cambrian, Permian, Jurassic, Cretaceous and Miocene ages; and limestones of the Paleocene and Eocene. The proven recoverable reserves are nearly 334 million barrels of oil and 23 Tcf of gas of which about 150 million barrels of oil and 5 Tcf of gas have been consumed.

The basin is divisible into large longitudinally oriented parallel tectonic features which are further subdivided into smaller petroleum zones by sub-latitudinally striking basement highs and transverse uplifts (Figure 1).

Tectonic Feature - A (Platform)

The platform is a relatively stable area that is a

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subsurface continuation of the Indian shield and contains sedimentary rocks of Paleozoic, Mesozoic and Cenozoic ages as well as recent alluvium. It has been little disturbed since Precambrian time except for general gentle warping and some rifting in the central area. The deformation is in the form of gentle tilts, folding and small scale faulting. Marine transgressions, regressions, overlaps and unconformities in the stratigraphic section provide evidence of sea-level fluctuation in response to local as well as world wide tectonic events.

Petroleum Zone A_1 (Punjab Monocline): The Punjab monocline is a generally westward sloping monocline with its northern edge downwarped to the north. The subsurface prolongation of the Sargodha high has shaped the Minawali re-entrant. The part of the monocline north of Sargodha high contains a thin section of marine Paleozoic and Tertiary strata, covered by Neogene fluviatile sediments. This part of the zone seems to have poor petroleum prospects. The area southwest of the Sargodha high is a vast gently dipping monocline containing moderate thickness of mainly marine Paleozoic, Mesozoic and Paleogene rocks covered by Neogene fluviatile sediments. The geophysical data have shown the presence of anticlines related to Salt intrusion of Precambrian age, paletopographic structures and possible stratigraphic traps. Two gas fields (Nandpur and Panjpir) have so far been discovered in Mesozoic sandstones. Paleozoic and Mesozoic sandstone plays appear to offer exploration potential.

Petroleum Zone A_2 (Sukkur Rift): On the basis of satellite imagery interpretation (Chaudhry, 1979), the central Sukkur area of the platform is considered a faulted rift structure comprising a graben (A_2 b: Pano Aqilgraben)and two horsts (A_2 a: Kandhkot-Mari and A_2 c: Jacobabad-Khairpur horsts). The Pano Aqil graben (A_2 b) is a continuation of the Cambay graben of India which contains several oil and gas fields (Cambay, Anklesvar, Kalol, Navagan etc). The producing horizons are of Eocene, Oligocene and Miocene ages.

The Kandhkot-Mari horst (A_2 a) consists of Mesozoic, Tertiary and Quaternary sediments. The Mari and Kandhkot structures have been drilled to the Cretaceous and gas has been discovered in Eocene carbonate reservoirs (Table 1). Gas has also been discovered in Eocene in Manari Tibba and Ghotara structures in Jaisalmer basin of India adjacent to the Kandhkot-Mari horst of the Pakistan. Mari gasfield with 4 Tcf of reserves is a giant field. On the east of Mari lies another structure (Sandh structure) which extends into India but its main crest is in Pakistan.

The Jacobabad-Khairpur horst (A_2 c) started becoming a positive area in Late Jurassic. It consists of Mesozoic, Tertiary and Quaternary sediments with the Cretaceous and Jurassic truncated and reduced in thickness over the horst. Low methane natural gas has been discovered in an Eocene carbonate reservoir on the huge Khairpur structure at a depth of 610 m. Gas shows were encountered in Triassic and Jurassic sandstones in the Jhatpat-1 well. Jacobabad-1 well blew out in Sui Main Limestone (Eocene).

Pano Aqil graben (A_2 b)appears to structurally offer a good area for generation and accumulation of hydrocarbons. Oligocene/Miocene and Eocene reservoirs are within reasonable drilling depths if suitable traps (probably fault traps) are seismically delineated.

Mesozoic and Tertiary plays are significant targets for exploration in the Jacobabad-Khairpur horst.

Petroleum Zone A_3 (Sind Monocline): The Sind monocline is a gently sloping monocline of Mesozoic and Cenozoic sediments deposited on a shelf. The zone is delineated by the Lakhra uplift in the west, and Nagar Parker high in the east. West of the Nagar Parker high, Cretaceous sands are producig oil and gas in a number of fields in Badin area (Figure 1). The structures producing oil and gas in Badin area are mainly fault traps related to Late Mesozoic rift phase (Figure 5).

Tectonic Feature-B (Depressions)

West of the platform is a belt of depressions. As a consequence of coalescence of Indian and Eursian plates, severe deformation of sediments has resulted near the plate boundaries and a fold belt was raised with simultaneous creation of a belt of depressions on the flank. The deformation front is progressing from west to east and north to south. The western flanks of the depressions are deformed and from east to west and south to north the structures become more basin of India adjacent to the of the Pakistan. Mari gasfi:ld giant field. On the east of Mari iandh structure) which extends crest is in Pakistan.

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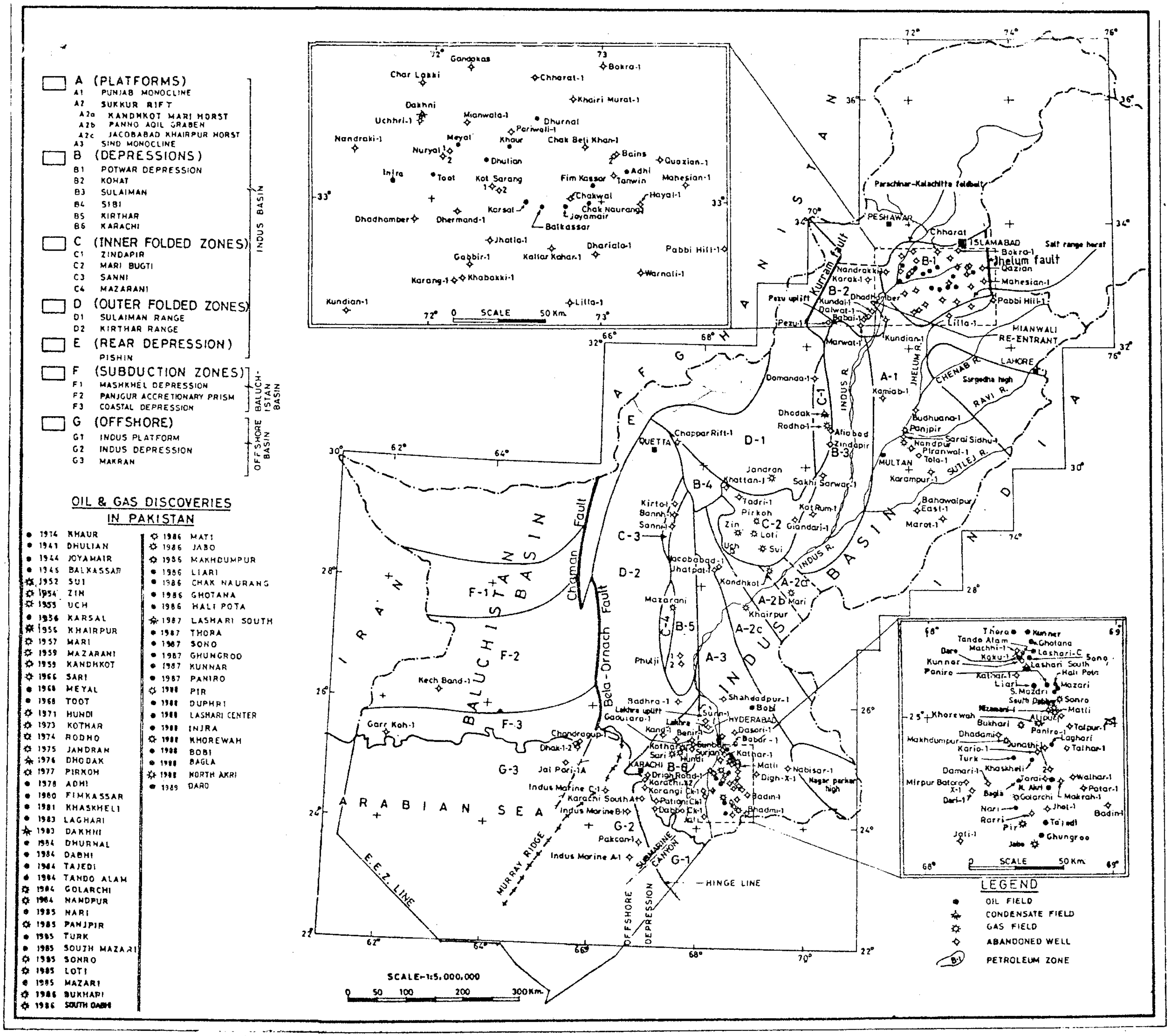

Figure 1. Well location of Pakistan with Petroleum zones.

Table 1. Oil and gas fields in Pakistan

Name	Region	Producing Horizon	Oil/Gas (Status)	Original Recoverable Reserves mmbbl/tcf *	Annual Production During 1988 bbl/mmcf **
1. Khaur (1915)	Potwar	Miocene Eocene	Oil (Producing)	4.290	2,798
2. Dhulian (1935)	"	Eocene Paleocene Jurassic	Oil/Ass. Gas (Producing)	41.328 0.199	8,776
3. Joya Mair (1944)	"	Eocene Cambrian	Oil (Producing)	7.130	158,449
4. Balkassar (1946)	"	Eocene	Oil (Producing)	32.120	158,595
5. Karsal (1956)	"	Eocene	Oil (Depleted)	0.208	—
6. Meyal (1968)	"	Eocene Paleocene Jurassic	Oil/Ass. Gas (Producing)	43.310 0.431	1,263,688 11,182
7. Toot (1968)	"	Eocene Jurassic	Oil/Ass. Gas (Producing)	14.500 0.043	475,836 2,299
8. Adhi (1978)	"	Eocene Permian Cambrian	Oil (Producing)	11.609	—
9. Fimkassar (1978)	"	Eocene	Oil (Depleted)	N.A.	2,626
10. Dakhni (1983)	"	Eocene Paleocene Jurassic	Oil/Gas (Dormant)	3.100 0.179	—
11. Dhurnal (1984)	"	Eocene Paleocene Permian	Oil/Ass. Gas (Producing)	51.800 0.126	6,588,859 15,364
12. Chak Naurang (1986)	"	Eocene	Oil (Producing)	32.959	267,697
13. Injra (1988)	"	Eocene Jurassic	Oil (Producing)	N.A.	6,576
14. Sui (1952)	Sulaiman	Eocene	Gas (Producing)	8.624	253,717
15. Zin (1954)	"	Eocene	Gas (Dormant)	0.100	—
16. Uch (1955)	"	Eocene	Gas (Dormant)	2.550	—
17. Mari (1957)	"	Eocene	Gas (Producing)	4.043	103,578
18. Kandhkot (1959)	"	Eocene	Gas (Producing)	0.796	13,761
19. Rodho (1974)	"	Paleocene Cretaceous	Gas (Dormant)	0.013	—

*milion barrles/triilion cubic feet. **barrels million cubic feet,

Table 1 (continued)

Name	Region	Producing Horizon	Oil/Gas (Status)	Original Recoverable Reserves mmbbl/tcf	Annual Production During 1988 bbl/mmcf
20. Jandran (1975)	”	Cretaceous	Gas (Dormant)	0.198	—
21. Dhodak (1976)	”	Cretaceous	Cond./Gas (Dormant)	25.480 0.700	—
22. Pirkoh (1978)	”	Cretaceous	Gas (Producing)	2.622	44,586
23. Nandpur (1984)	”	Cretaceous Jurassic	Gas (Dormant)	0.427	—
24. Panjpir (1985)	”	Cretaceous	Gas (Dormant)	0.010	—
25. Loti (1985)	”	Eocene Paleocene Cretaceous	Gas (Dormant)	0.755	—
26. Khairpur (1956)	Kirthar	Eocene	Gas (Dormant)	1.000	—
27. Mazarani (1959)	”	Eocene	Gas/Cond. (Dormant)	0.091	—
28. Sari (1966)	”	Paleocene	Gas (Depleted) }	0.065	135
29. Hundi (1971)	”	Paleocene	Gas (Depleted) }		
30. Kothar (1973)	”	Paleocene	Gas/Cond. (Dormant)	0.017	—
31. Khaskheli (1981)	”	Cretaceous	Oil/Ass. Gas (Producing)	7.572 0.002	281,710
32. Laghari (1983)	”	Cretaceous	Oil/Ass. Gas (Producing)	13.000 0.001	1,920,125
33. Dabhi (1984)	”	Cretaceous	Oil/Ass. Gas (Producing)	3.166 0.016	409,928
34. Tajedi (1984)	”	Cretaceous	Oil (Dormant)	0.215	—
35. Tando Alam (1984)	”	Cretaceous	Oil (Producing)	9.378	942,567
36. Golarchi (1984)	”	Cretaceous	Gas (Dormant)	0.024	—
37. Nari (1984)	”	Cretaceous	Oil/Ass. Gas (Dormant)	0.285 0.019	—
38. Turk (1985)	”	Cretaceous	Oil (Dormant)	0.197 0.060	—
39. Mazari (1985)	”	Cretaceous	Oil (Producing)	9.772 0.090	2,480,010
40. S. Mazari (1985)	”	Cretaceous	Oil (Producing)	2.161	315,227
41. Sonro (1985)	”	Cretaceous	Oil (Dormant)	1.902 0.066	—

Table 1 (continued)

Name		Region	Producing Horizon	Oil/Gas (Status)	Original Recoverable Reserves mmbbl/tcf	Annual Production During 1988 bbl/mmcf
42.	Bukhari (1986)	"	Cretaceous	Oil (Dormant)	N.A	—
43.	S. Dabbi (1986)	Kirthar	Cretaceous	Gas (Dormant)	0.004	—
44.	Matli (1986)	"	Cretaceous	Gas (Dormant)	0.005	—
45.	Jabo (1986)	"	Cretaceous	Gas (Dormant)	0.003	-
46.	Makhdumpur (1986)	"	Cretaceous	Gas (Dormant)	0.016	—
47.	Liari (1986)	"	Cretaceous	Oil (Dormant)	0.854	—
48.	Ghotana (1986)	"	Cretaceous	Oil (Producing)	0.200	47,322
49.	Hali Pota (1986)	"	Cretaceous	Oil (Dormant)	0.691	—
50.	Lashari-south (1987)	"	Cretaceous	Gas/Cond.	N.A. 0.087	—
51.	Thora (1987)	"	Cretaceous	Oil (Producing)	4.220	830,185
52.	Sono (1988)	"	Cretaceous	Oil (Producing)	7.260	403,674
53.	Ghangroo (1988)	"	Cretaceous	Oil	1.359	—
54.	Kunar (1988)	"	Cretaceous	Oil	8.600	—
55.	Panero (1988)	"	Cretaceous	Oil	N.A.	—
56.	Pir (1988)	"	Cretaceous	Gas	N.A.	—
57.	Duphri (1988)	"	Cretaceous	Oil	N.A.	—
58.	Lashari-centre (1988)	"	Cretaceous	Oil (Producing)	3.250	38,402
59.	Khorewah (1988)	"	Cretaceous	Gas	N.A.	
60.	Bobi (1988)	"	Cretaceous	Oil	0.720	—
61.	Bagla (1988)	"	Cretaceous	Gas	N.A.	—
62.	N. Akri (1988)	"	Cretaceous	Oil	N.A.	—
63.	Daro (1989)	"	Cretaceous	Oil	N.A.	

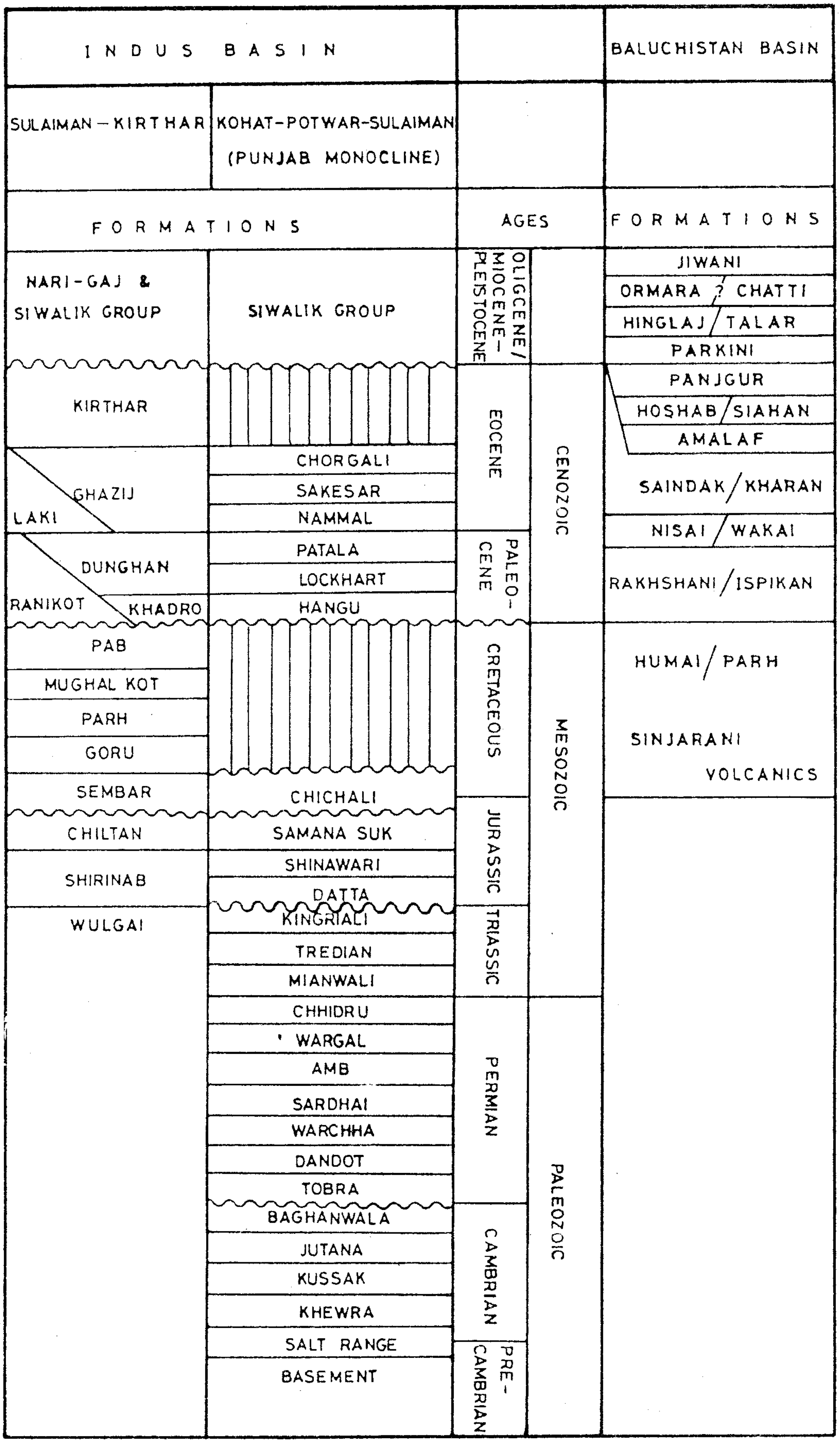

Figure 2 a. Stratigraphic nomenclature of Indus and Baluchistan basins.

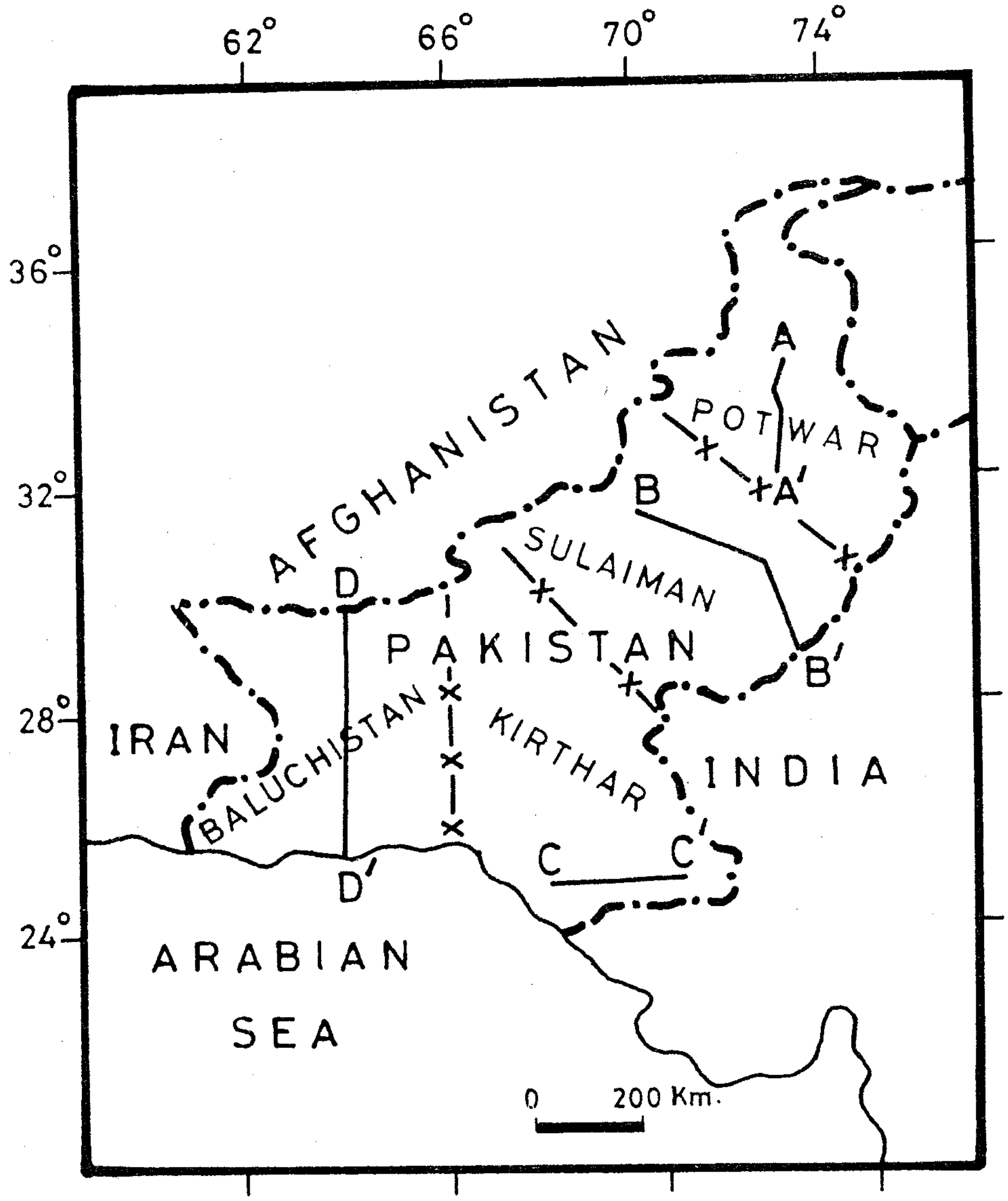

Figure 2b. Location of sections and sedimentary regions in figures 3, 4, 5 & 7 and table 1.

complicated. The depressions are covered with thick Quarternary deposits characterized by the occurrence of multiple unconformities.

The belt of depressions comprises six petroleum zones, *viz*. Potwar, Kohat, Sulaiman, Sibi, Kirthar and Karachi depressions.

Petroleum Zones B_1 and B_2 (Potwar and Kohat Depressin): The two zones form a composite depression which is bounded in the north by Parachinar-Kalachitta foldbelt through a system of faults. The Salt Range horst marks its southern limit. Southwestward, it is separated from the Sulaiman depression by the Pezu uplift. Its western and eastern limits are respectively marked by the Kurram and Jhelum faults.

The main sediments supply during Tertiary appears to be derived from the rising Himalayas with uplift ending during the Late Pleistocene. The Salt Range is considered to be created by blocking of the moving thrust sheets from north by a basement fault block (Lillie, 1986). The Bannu trough which is marked by the recent alluvial deposits is still downwarping northwestward. The region contains sediments from Precambrian to Pleistocene age (Figure 2). The structures in the north are tight and faulted (Figure 3). In the northern part of the Kohat depression Eocene salt has cut through the core of anticlines. The structures on the eastern side are narrow anticlines flanked by wide synclines. The structures in the central part of both Kohat and Potwar depressions are relatively simpler. The Salt Range which also includes trans-Indus ranges contains large composite anticlinal trends.

The zone B_1 (Potwar depression) is a major oil producing province of the country with production from Jurassic, Paleocene and Eocene rocks. Some discoveries have also been made in Cambrian and Permian. The zone B_2 (Kohat depression) still remains a virgin area and holds good prospects for oil. Paleozoic, Mesozoic and Tertiary hydrocarbon plays merit investigation and estimation in the two depressions.

Petroleum Zone B_3 (Sulaiman Depression): The large downwarp is contemporary with the Potwar-Kohat depression. The sediment fill is of Paleozoic, Mesozoic and Cenozoic age and it is covered by Quaternary alluvium and Neogene molasse. Sharp decrease in the thickness of various rock units towards east is noted from subsurface data (Figure 4). Simple anticlines, and formation of subtle traps connected with pinch-outs and unconformities in the eastern side, offer good prospects for petroleum.

Petroleum Zone B_4 (Sibi Depression): The Sibi depression is a narrow, triangular depression sandwiched between the Sulaiman and Kirthar ranges (Figure 1). Its northern rim is much more elevated than the southern flank. The depression opens towards Kirthar depression in the south. Bounded by faults, it has the appearance of a graben. The folds are generally oriented perpendicular to the elongation of the depression. The anticlines are narrow and asymmetric, and synclines are low and wide.

The depression developed from Miocene time and since then was filled by huge thickness of continental molasse. The hydrocarbon prospects of the central area with varying thickness of continental molasse cover seem to be limited to Paleogene rocks, however exploration is required to delineate traps. The folds on the flanks have some prospects in Eocene carbonates and Cretaceous sands.

Petroleum Zone B_5 (Kirthar Depression): This zone is a north-south trending downwarp south of the Sibi depression. Its western limit is marked by the Sanni and Mazarani folded zones. It has faulted eastern boundary with the Sind monocline. We interpret that the Lakhra uplift which started emerging contemporaneously with pre-Tertiary rifting was the main cause of this fault. The molasse here is quite thick as in other depressions. Apparently, the area seems nearly flat, but the possibility of some structural traps developed due to basement flexures can not be ruled out. There are various possibilities of development of stratigraphic traps in Paleogene sediments. Some oil and gas shows in the northwestern flank of the depression indicate evidence for generation of hydrocarbons. Tertiary and Mesozoic plays are worth investigating.

Petroleum Zone B_6 (Karachi Depression): The Karachi depression is an embayment opening up into Arabian Sea. The northern part of the depression is raised while the southern part is submerged under the

POTWAR REGION

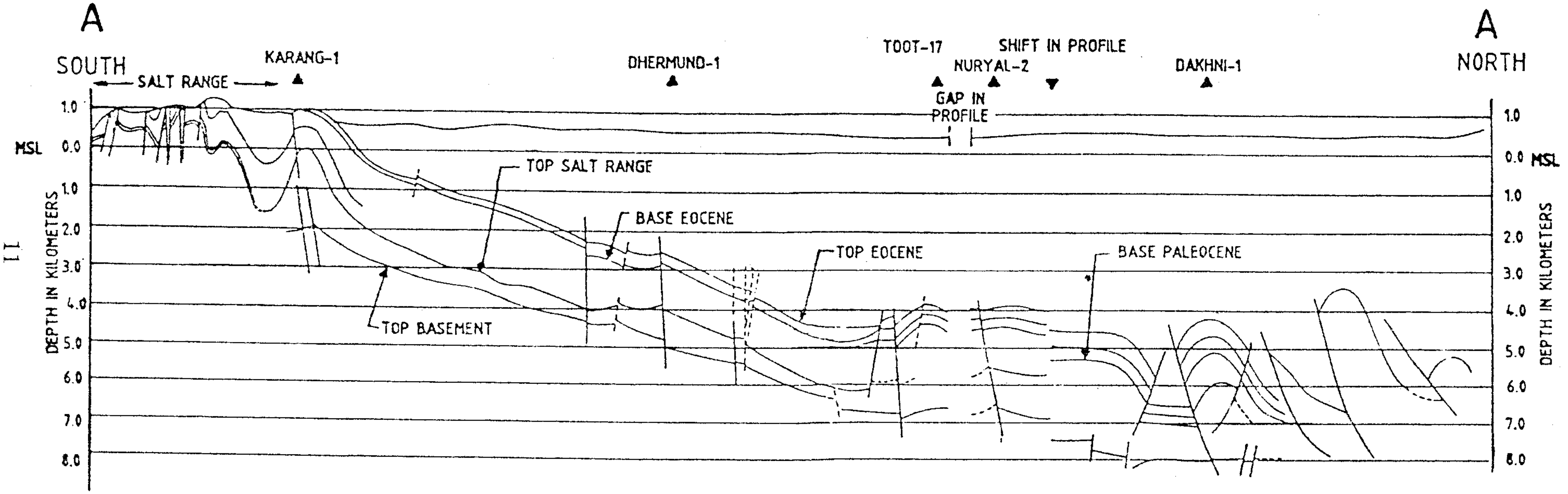

Figure 3. Geological section across Potwar region (modified after Altenkirch et al. 1987).

Figure 4. Geological section across Sulaiman region.

sea. It contains thick Neogene and Palaeogene marine sediments underlain by Mesozoic rocks. The zone contains a lare number of surface ridge-like narrow chains of anticlines oriented meridionally and sub-meridionally. The area contains a few small gas fields like Sari, Hundi and Kothar in Paleocene carbonate reservoirs. Oil and gas shows have also been encountered in Oilgocene and Cretaceous rocks. Cretaceous and Tertiary plays need to be investigated.

Tectonic Feature-C (Inner Folded Zones)

The western flanks of the Sulaiman and Kirthar depression are bounded by uplifted and folded zones comprising Zindapir, Mari-Bugti, Sanni and Mazarani zones. Parachinar-Kalachitta fault-fold zone bounding Kohat-Potwar depression in the north is for the time being excluded because of our poor knowledge of the subsurface picture beneath this complex zone. These zones also represented deformation front which is progressing eastward. Here the uplift has brought prospective reservoirs higher in trap conditions, thus enhancing oil and gas prospects. The anticlines are in the form of box-like folded zones forming pronounced ridges passing into wide synclines. There are large number of gas fields in these zones.

Petroleum Zone C_1 (Zindapir Folded Zone): The Zindapir Folded zone is a north-south elongated narrow region flanking the Sulaiman depression in the west and is comprised of the Sakhi Sarwar, Zindapir, Afiband, Rodho and Dhodak anticlines all of which have steep eastern limbs and gentle western flanks. This chain of ridge-forming anticlines turns westwards in the south and seems to merge with the Mari-Bugti folded zone. Condensate from Dhodak and gas from Rodho structures have been discovered in a Cretaceous sandstone reservoir. All the available structures in the zone have been tested. The two discovered fields are yet to be exploited.

Petroleum Zone C_2 (Mari-Bugti Folded Zone): The Mari-Bugti comprises three chains of anticlines with intervening synclines. The folds are sub-latitudinally arranged and increase in amplitude and deformation northwards. The chains are: (1) Sui-Uch, (2) Giandari-Loti-Zin and (3) Shamkalik-Pirkoh-Bambor. Neogene molasse covers the Sui-Uch sub-zone, whereas various horizons of Paleogene form the central parts of the Giandari-Loti-Zin and Shamkalik-Pirkoh-Bambor sub-zones. The area is mainly gas-prone and contains many gasfields including the giant Sui field, but some oil shows are present in its northwestern edge. The Cretaceous and Eocene plays need to be further evaluated.

Petroleum Zones C_3 (Sanni Folded Zone): The Sanni is a narrow folded zone flanking the Kirthar depression in the west. The zone is longitudinally oriented and comprises Sanni and Bannh anticlinal sub-zones which expose marine Eocene and continental Oligocene sediments in the central parts of the anticlines. The zone is downwarping northeastwards. Oil seepages are present in the zone.

Petroleum Zone C_4 (Mazarani Folded Zone): The Mazarani zone is the southern extension of zone C_3, west of the Kirthar depression. Like Sanni zone (C_3), it also has a longitudinal orientation. The zone comprises a northern anticlinal uplift (Mazarani anticline, which contains gas and condensate in Lower Eocene carbonates) and a southern updip sloping towards the Kirthar depression. Eocene and Cretaceous plays merit investigation.

Tectonic Feature-D (Outer Folded Zones)

The depressions are succeeded in the north and west by a mountain belt comprising Parachinar-Kalachitta, Sulaiman and Kirthar ranges. These ranges were produced during the Tertiary by collision & coalescene of the Indian and Eurasian plates. In the present paper only Sulaiman and Kirthar ranges are discussed because the Parachinar-Kalachita ranges, according to our present level of information, hold some hydrocarbon potential in the subthrust zones; where trap delineation can only be done through intensive seismic survey.

Petroleum Zones D_1 and D_2 (Sulaiman and Kirthar Ranges): As discussed earlier, these zones represent the deformed and uplifted areas of the Indus basin because of their position near the collision front.

The Sulaiman range swings from north-south to east-west forming an arcuate chain. Western part of the chain is formed of Fort Sundeman-Loralai subzone. Older rocks (mainly Mesozoic) are exposed in sharp folds often complicated by faults. The part close to Zindapir and Mari-Bugti folded zones contains some interesting anticlinal folds which can be considered as

KIRTHAR REGION

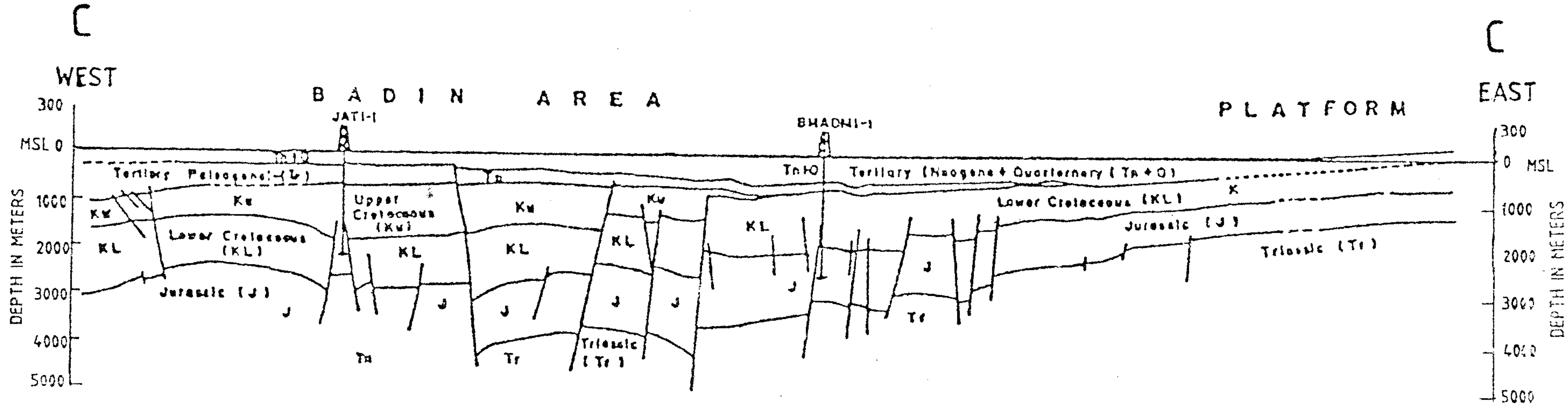

Figure 5. Geological section across Kirthar region (modified after Malik et al. 1988).

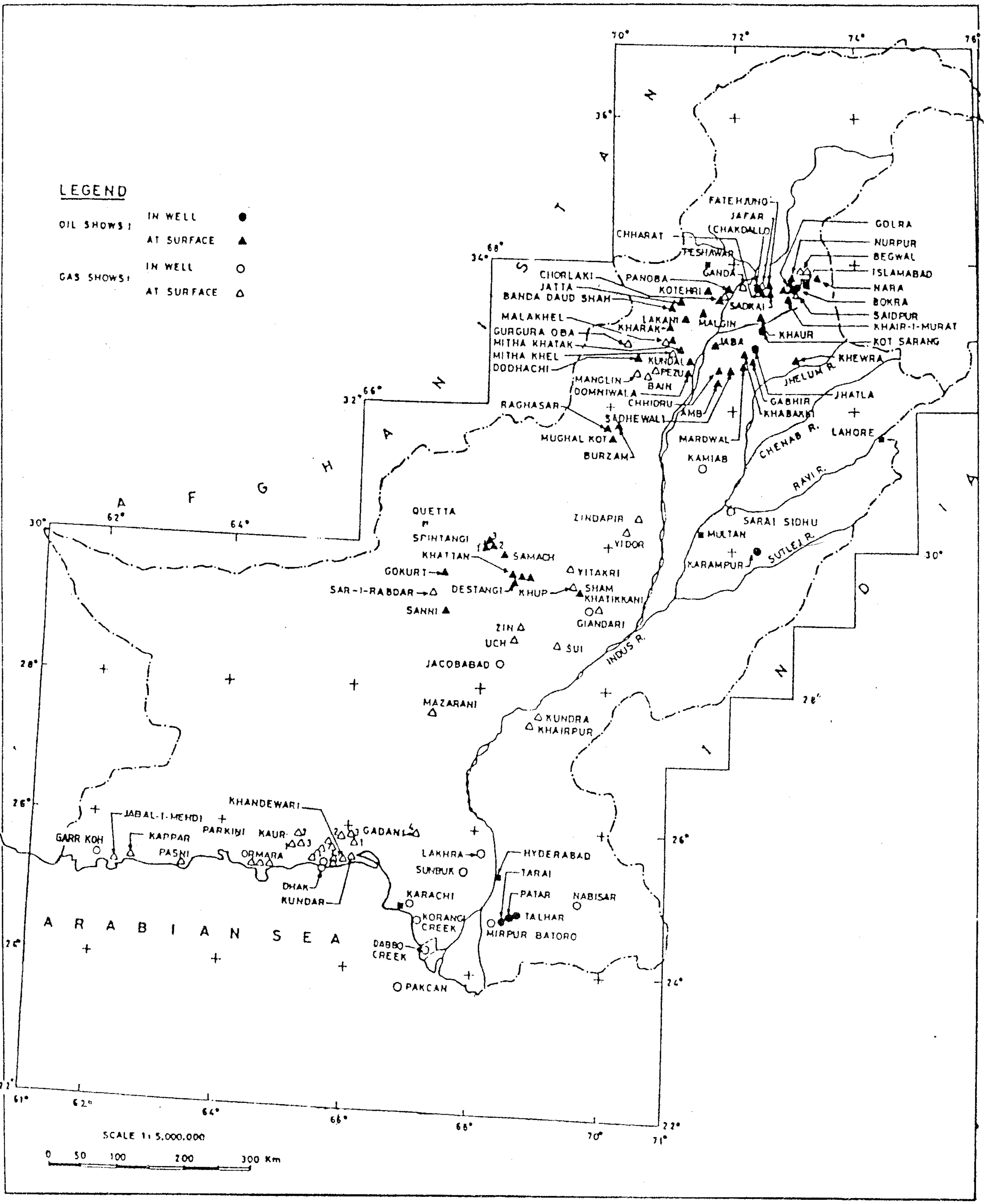

Figure 6. Oil and gas seepages/shows in Pakistan.

potential exploration targets. A gas field (Jandran) in the Cretaceous reservoir and a number of oil seepages in the eastern part of the zone prompt investigation and evaluation of the Cretaceous (Figure 6).

The Kirthar Range runs in a north-south direction. The inner or western folded subzones of Fort Sandeman-Loralai continue into the Kirthar Range and are represented by Quetta and Mor subzones. The eastern or outer part of the Kirthar Range contains Bolan and Gaj anticlinal subzones formed by Mesozoic-Neogene sediments. This part has some potential for hydrocarbon in the Jurassic and Paleogene plays as indicated by the occurrence of oil seepages at Harnai, Bibi Nani and Gokurt.

Tectonic Feature–E (Rear Depression)

It occurs in between the Chaman fault and the obducted ophiolitic margin of the Indian plate. The boundary of the rear depression follows the pattern of Sulaiman and Kirthar ranges, although sediments infill and tectonics are not identical. Turbiditic sequences ranging in age from Oligocene-Miocene pile up in the basin with sporadic exposures of Eocene carbonates. Tight anticlines, broad synclines and northwardly dipping thrusts are characteristic features. Dark shales associated with turbidites are considered as potential source rock. There is no dearth of structures with large closures.

Petroleum Zone E (Pishin Depression): This depression is filled with fine clastics of Cenozoic age underlain by Eocene carbonates. The sediments have been strongly deformed, sheared, folded, faulted and refolded. The synclines have occupied high relief position and anticilines have slipped in depression. The complicated structural geology demands careful evaluation of the zone.

Baluchistan Basin

The Baluchistan basin can be classified as Extracontinental Subduction Basin (Riva, 1983). The producing capacity of such basins ranges from 4,800 to 72,012 barrels of oil or equivalent gas per cubic kilometer of sediment. Although oil geologists generally show some prejudice toward such basins and consider low heat flow and quality of reservoir rocks and traps suspect, the occurrence of hydrocarbons in these basins is not infrequent. Subduction basins of California, Barbodas, Equador, Phillipines, Peru, Indonesia, etc. having geologic setting similar to the Baluchistan basin, are producing oil and gas in commercial quantities. The Baluchistan sedimentary basin has the status of a frontier basin and little exploration has conducted.

The magmatic arc and inter-arc zones, which contain Cretaceous-Paleogene sediments complimented with volcanic rocks (Figure 2) are not discussed in the present report because of their insignificant petroleum potential. The rest of the basin, which is principally filled with sedimentary rocks of Oligocene-Recent age with sporadic exposures of Cretaceous to Eocene sediments, is sub-divided into three petroleum zones. The effective sedimentary area of the basin within the territory of Pakistan measures approximately 400 × 500 km and contains more than 5 km thick sedimentary fill (Figure 7). Several gas shows with traces of heavy hydrocarbon are reported from Baluchistan basin. To date no oil or gas field has been discovered from the basin, except some accumulation of natural gas in one exploratory well (Garr Koh-1). Although the accumulation is in non-commercial quantity, it has significant bearing on the petroleum geology of the region. Two km thick mudstone horizon (Parkini) containing disperssed organic matter is considered as fair source rock. These horizons are fairly mature to generate hydrocarbon especially in areas where buried under the overburden of more than 5 km thick shelf sediment. Target reservoirs are Pliocene shelf sandstone and Miocene turbidites which are expected at drillable depths.

Tectonic Feature–F (Subduction Zones)

The feature is situated between the northern magmatic arc region and the Arabian Sea. Its structural trends start from the Chaman-Bela-Ornach transform fault zone in the east and extend westward beyond the border of Pakistan. The feature exhibits progressively southward shifting tectonism and sedimentation. Three parallel petroleum zones based on the evolution of accretionary complex are recognized from north to south.

Petroleum Zone F_1 (Mashkhel Depression): The Mashkhel depression represents a flat area of Hamun-i-Mashkhel and Kharan Desert, covered by Quaternary sands. Aeromagnetic surveys have confirmed the presence of depressions containing huge thickness of

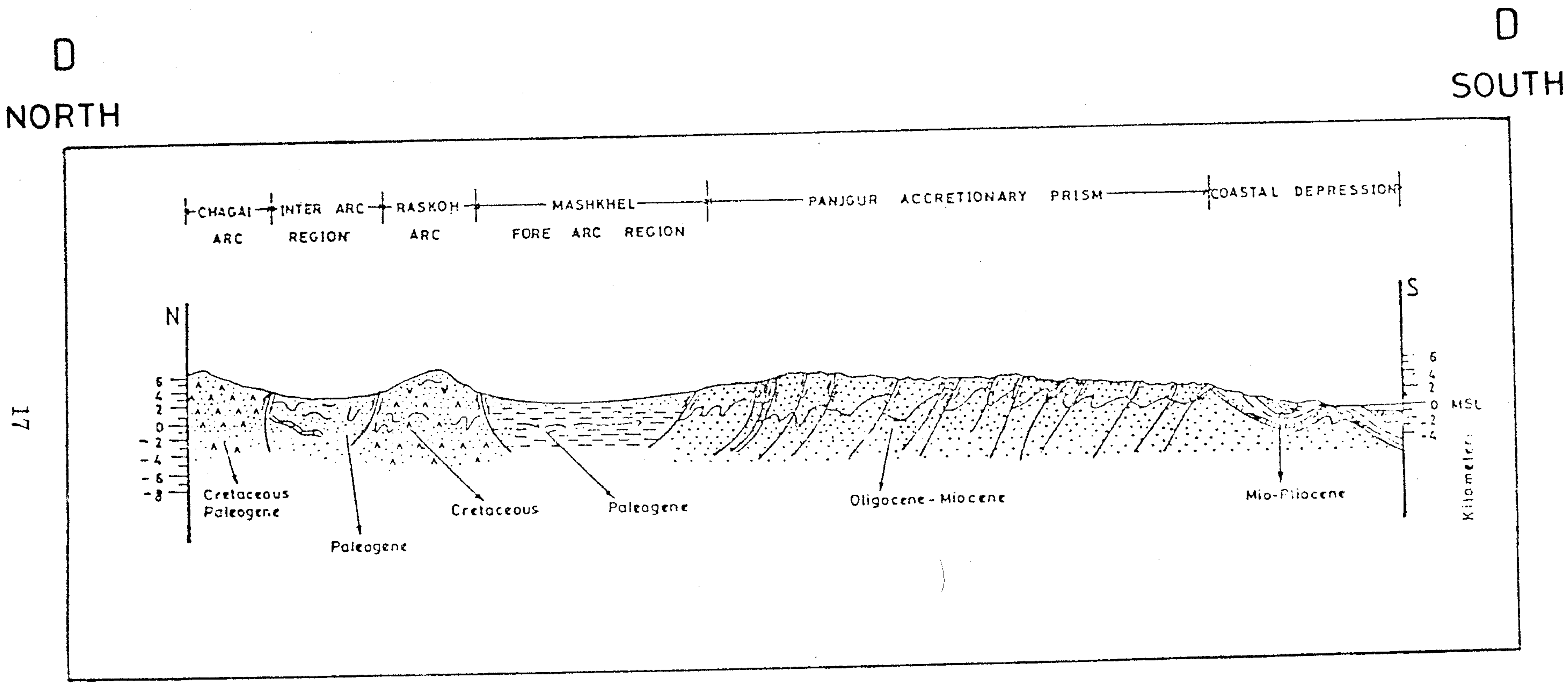

Figure 7. Geological section across Baluchistan basin.

sedimentary rocks of possible Paleogene age. Seismic survey is required to delineate subsurface structures.

Petroleum Zone F_2 (Panjgur Accretionary Prism): It is a prism formed by thrusting up of accretionary sediments in front of the fore-arc region. The anticlinal folds, with intervening broad synclines, strike east west and are asymmetric, steep to overturned, sharp, frequently truncated by reverse faults at the southern flank. Miocene sandstones are objectives of investigation and evaluation.

Petroleum Zone F_3 (Coastal Depression): The zone represents the coastal Makran region. The tectonic style in the zone is characterized by huge synclines flanked by small anticlines. Reverse faults are less common in this zone as compared to the accretionary prism. It is interpreted that a number of anticlinal structures may be developed as rollovers next to a regional listric growth fault along the coast. Additional stratigraphic traps towards the southern flanks of the synclines are produced due to facies changes in Pliocene shelf sandstone. Kapper dome striking north-south and dipping into the sea represents another departure from the regional trend and is speculated to be effected by some mud diaprism. Miocene-Pliocene shelf sandstones are the target plays in addition to Miocene turbidites.

Tectronic Feature–G (Offshore)

A vast offshore area of Pakistan measuring approximately 240,000 sq. km is situated in the south of the country between long. 61° 45′ and 68° 10′. Tectonically, it is divisible into (1) Offshore Indus with a continental crust and (2) Offshore Makran having an oceanic crust. The Murray ridge and Owen fracture zone form a transition plate boundary between the two.

Petroleum Zone G_1 (Indus Platform): It is a platform area which is prolongation of the onshore Sind monocline. The zone is cut in the south-eastern corner by a submarine canyon of the Indus river. The region is dominated by intricate drainage pattern of many mouths of the Indus river. The stratigraphy in the area is similar to the onshore Sind monocline. The structures are oriented in northwest-southeast direction. Cretaceous, Eocene and Oligo-Miocene are objective plays in the zone.

Petroleum Zone G_2 (Indus Depression): The zone represents a deep depression which appears to be a direct prolongation of the onshore Karachi depression. The area is severely faulted by sinuous and gravity growth faults. The southwestern margin of this depression is bounded by a gentle uplift running parallel to the axis of the deep. Eocene and Oligo-Miocene plays are the objectives of investigation.

Petroleum Zone G_3 (Makran)): The zone covers the region in between the coastal depression zone (F 3) and east-west oriented trench, where the Arabian plate is being subducted beneath the Eurasion plate (Jacob & Quittmeyer, 1979). Accreted sediment pile at the prism front is succeeded by slope mantling mud facies and southward prograding shelf wedge. The intensity of tectonic deformation is relatively mild. The resulting simple fold closures in abyssal plain and slope sediments hold prospects worth investigating. Stratigraphic traps due to facies changes may be the other alternative targets for exploration.

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