Petroleum Potential of Kalachitta-Margala Hills Range and Adjoining Peshawar-Hazara Basin, Pakistan*

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Abstract

The Kalachitta-Margala Hills Range and adjoining Peshawar-Hazara Basin occur in the north of Islamabad, the capital city of Pakistan and extends towards Kohat in the west. This area constitutes the northwestern margin of the Indo-Pakistan Plate in the western Himalayas in Pakistan.

Thick sedimentary pile, reported oil seepages and proximity to hydrocarbon producing Potwar-Kohat Basin make it prospective for exploration. Complex structural style and nature of the presumed Main Boundary Thrust (MBT) of the central and eastern Himalaya is considered to have significant implications on hydrocarbon assessment of the area.

Geological investigations have revealed that the molasse sediments of the northern Potwar, at many places, are in normal stratigraphic contact with the underlying calcareous sediments of the Indo-Pakistan Plate. A major fault like MBT along the Kalachitta-Margala Hills Range - the frontal part of the Hazara fold belt, could not be confirmed. These factors coupled with the occurrence of oil seepages suggest likely generation, migration and accumulation of hydrocarbon in the Kalachitta-Margala Hills Range and adjoining Peshawar- Hazara Basins.

Introduction

The Kalachitta-Margala Hills Range topographically separates Peshawar-Hazara Basin in the north from the Kohat-Potwar Basin in the south. Both are part of the western Himalayas in Pakistan (Figure 1). Within the region potential source, reservoir and seal rocks exist. Anticlinal structures are possible traps. Oil seepages at Golra and a recent one from shallow water well in the Balochistan House, Islamabad prove the generation and migration of hydrocarbon in the kitchen area.

The first discovery of oil in the sub continent was made at Khaur (1915) in Potwar Basin followed by a number of significant ones until recently. Surprise discoveries in Kohat Basin (Makori, Manzalai, Chanda and Mela) in the strike extension of the Potwar Basin enhance the confidence level of explorationists. With this approach, Peshawar-Hazara Basin and Kalachitta-Margala Hills Range are considered to have good prospectivity. This paper incorporates the work of the previous workers aiming to establish relationship between their interpretation and the petroleum prospectivity of the region.

Data synthesis leads to two observations; firstly; the stratigraphic contact, between platform rocks of the Indo-Pakistan Plate and overlying molasse sediments (Murree Formation) of the northern Potwar at places, is normal. Secondly; despite strongly tectonised structures, no persistent regional thrust-like MBT of the eastern and central Himalayas was recorded in this segment of the western Himalaya. These observations suggest that Kalachitta-Margala Hills Range, which is towering in the north of the Potwar-Kohat Basin, has been formed as an overturned fold rather than a major fault. This finding, which enhances the petroleum prospectivity of the region, is discussed in this paper.

Previous Work

Waagen and Wynne (1872) wrote a report about the stratigraphy of the Abbottabad Hazara. Middlemiss prepared the geological map of the area extending from Black Mountains in the west to Kunhar River in the east in 1896. He introduced the term Main Boundary Thrust.

Wadia (1931) used the term "syntaxis" for the sharply bending mountains around Muzaffarabad. Two important thrusts, namely Panjal and Murree thrusts, were reported by him. The Panjal Thrust is an inner thrust and a regional sliding plane for a large Kashmir Nappe. It brings slates and schists of the Precambrian Purana Series from the central mountains over Carboniferous to Eocene age rocks in the south. The Murree Thrust is the outer thrust. It is a reverse fault which brings Carboniferous through Eocene age rocks southward over Murree Formation.

Pascoe used the term Great Boundary Fault in 1963 for the Main Boundary Fault of Middlemiss. He considered that Great Boundary thrust is the northern most limits of the molasse sediments. However, in 1963 he became convinced that the term Boundary Fault is a misnomer as molasse sediments were then reported to the north of that fracture.

Latif (1968) published a geological map and stratigraphic scheme for the southern Hazara. He divided the area into seven groups and twenty-one formations. Each group was separated by an unconformity. Calkins et al., (1975) conducted structural investigations in the Hazara. They divided the area into three structural blocks namely; Hazara- Kashmir Syntaxis, Western Arc, and Indus Re-entrant. The Panjal, Murree, and Darband faults separate these blocks. They suggested that the Murree and Panjal faults are steeply dipping reverse faults on the eastern limb and vertical on the western limb of the of the Hazara-Kashmir syntaxis north of Balakot.

McDougall et al., (1993) suggested that the Main Boundary Thrust is a floor thrust along which a thrust system incorporating Precambrian and Phanerozoic rocks of the Kalachitta and Attock-Cherat ranges was emplaced over Cenozoic strata of the northern Kohat and Potwar Plateau.

In view of the above-mentioned description, it is clear that MBT represents a fault between the Mesozoic shelf sediments of the Indo-Pakistan Plate lying tectonically over the molasse of the Kohat-Potwar Plateau (foreland basin). In other words, Peshawar-Hazara Basin in the north and Potwar-Kohat Basins in the south have been separated by a regional fault- generally assumed MBT - along the Kala-Chitta-Margala Hills Range.

Stratigraphy

The stratigraphic succession encountered during the work starts with the Jurassic Samana Suk Limestone and ends with the Miocene Murree Formation (Table 1).

Geological Setting

The area under discussion constitutes a part of the western Himalayas in Pakistan. It has been formed due to collision of Indian and Eurasian plates. Due to collision, prominent regional structural elements have been developed along the consuming plate boundaries. The geology and structure of the western Himalayas has been well documented by several workers. Mujtaba (1991) has shown that in western Himalayas, the Indus Suture Zone (ISZ) bifurcates into two structural zones, the Main Mantle Thrust (MMT) and the Main Karakoram Thrust (MKT). These sutures surround the obducted Kohistan Arc. The MKT, the northern suture, separates the intrusive and high-grade metamorphic rocks of Eurasian Plate from the Kohistan Arc terrane. The Kohistan Arc terrane has, on the northern edge, deformed gabbro, volcanics and greywacke (Rakaposhi Volcanics Complex) that are intruded by tonalite, diorites and pegmatites. To the south, the rocks are composed of a deformed, layered igneous complex metamorphosed to granulite facies. The southern most rocks of the Kohistan Arc are metasediments, amphibolites' and granites. The MMT, the southern suture, separates the Kohistan Arc from the metasediments on the northern edge of the Indian Plate. It is the extension of the Indus-Tsangpo suture. The northern edge of the MMT is marked by sporadic occurrences of ultramafic rocks. The Indian Plate rocks are late Precambrian to early Paleozoic schists, marbles, gneisses and granitic gneisses that have been thrust southward over the Tertiary molasse sediments of the Rawalpindi and Siwalik Groups. Southward thrusting continues within the molasse sediments, which is the evidence of continued convergence of the Indian and Eurasian plates.

As a result of tectonic activities several discontinuities in the sttratigraphic record have been recorded (Table 1). Since Jurassic more than 670 m of marine sediments have been deposited against more than 7,500 m thick molasse from Miocene onwards (Sheikh, M.Iqbal et al., 1993). Since then intense deformation, erosion and subsidence dominated and thick deposition of coarse clastic continental sediments took place. During the uplift and structural deformation for the last 1.5 million years (Plio-Pleistocene), erosion remained more pronounced than deposition, so the preserved sediments are thin and discontinuous bodies of alluvium and eolian silts are seen.

Structural Geology

The Main Boundary Thrust

Generally, it is believed that the Main Boundary Thrust (MBT) that is an important fault of the central and eastern Himalaya (India and Nepal, respectively) is extending to the area under investigation. In this paper, the nature of the reported MBT is discussed. It is considered that the existence or absence of the MBT in the regional tectonic perspective has great bearing on the petroleum assessment. For precise location of the MBT, study of stratigraphy and structures was envisaged as a prerequisite. For this purpose, traverses along the eastern segment of the area between Langrial (Karakki), Islamabad and Ghoragali (Figure 2, Appendix 1) were made.

In the central and eastern portions of the collision zone, in India and Nepal, MBT delineates the frontal part of the doubled Indian crust. There, metamorphic Indian Plate basement rocks are underplated by the advancing and intact main body of the Indian Plate. In western Nepal, MBT separates the metamorphics of the lesser Himalayas from Siwaliks (Kaphle, K.P.1992). The uplift of the Himalaya is attributed to the buoyancy of the doubled sialic crust over the mantle material (Gupta and Narain, 1967; Kono, 1974: Choudhury, 1975; LeFort, 1975; Mattauer, 1975; Powell and Conaghan, 1973). There, along the MBT the metamorphic rocks are thrusted on Siwaliks.

As evident from the previous work (Middlemiss, 1896 and Pascoe, 1963) in Pakistan, MBT is considered a regional fault that demarcates the southern limit of the Peshawar-Hazara Basin or it tectonically brings Mesozoic-Tertiary marine sequence of the Indo-Pakistan Plate over the molasse (Murree Formation) sediments. MBT runs east-west in the east of the Jhelum Re-entrant and swings around to the west and then to the south roughly east of Balakot. Northeast of Islamabad, it gradually moves again to an east-west direction along the Murree Fault (Figure 1).

Iqbal and Bannert (1998) have mentioned the following reservations of the previous workers about the cited scheme of MBT.

1. Along the Murree Fault, only sedimentary and no metamorphic rocks are in contact with the molasse sediments of the Murree Formation (Pascoe, 1963).
2. There is no doubled crust of the Indian Plate under the Peshawar Basin (Davies and Lillie, 1994).
3. The structure of northern Pakistan is not influenced by subduction and underplating below the Main Mantle Thrust (Indus-Tsangpo- Suture Zone). It is subducted under the Kohistan Island Arc Complex.
4. Metamorphic rocks north of the Margala Hills occur near Attock, roughly 75 km to the south of the Dargai ultrabasic rocks. These mark the Main Mantle Thrust (MMT). The Peshawar Basin occupies the area between Attock and Dargai and cannot be considered as an indication of doubled sialic crust.
5. Earthquake distribution to the north of the Jhelum Reentrant shows no indication of a bending and southwestward continuation of the MBT (Armbruster et aI., 1978).
6. In the area under consideration, the Murree Fault is difficult to define.

In the light of the above discussion, the nature of the MBT was investigated and it was found that a far-reaching regional fault like MBT does not extend at least to the area under investigation. This conclusion is based on the following interpretation.

Major Structural Elements of the Area

The geological map (Appendix 1) shows that sediments of Murree Formation cover the south and southeastern part of the Kalachitta-Margala Hills. Islamabad-Ghoragali road is running within this sequence. Eocene-Paleocene rocks, with sporadic exposure of Jurassic rocks in the core of a few anticlines, cover the major part of the hill range in the north of Islamabad. The calcareous and molasse sequences are generally trending in NE-SW direction as narrow structures. These have been folded during the Himalayan orogenesis. Iqbal and Bannert, (1998), from south to north, have briefly described the following major structures.

1. The Mandla-Tret Anticline
2. The Nurpur-Pithli Anticline
3. The Margala Hills Anticlinorium
   A. The Shah Allahditta –Islamabad Segment:
   B. The Islamabad-Shahdara Segment:
   C. The Shahdara-Bashkoli Segment
4. The Dalhor-Gambhir Anticline
5. The area northwest of the Lora Synclinorium
6. The Mount Dubran fold and thrust structure

1. The Mandla-Tret Anticline

The Mandla-Tret Anticline is located in the north of Bharakau, Islamabad. The core of the anticline is made up of limestone of various ages. Between Mandla and Tret, Chorgali Formation occurs in the core. In Ghoragali, along the road to Langrial tectonised Lockhart Limestone, dipping 315°/48° builds its core. Although the Mandla-Tret Anticline has strongly faulted contacts at Ghoragali, it is worth mentioning that in the west at Mandla the core of Chorgali Limestone is flanked on both sides by Kuldana Formation. At the southern flank of the anticline at Mandla, the Kuldana Formation is concordantly overlain by Murree Formation. A syncline of folded Murree Formation and Kuldana Formation exists to the north. From Tret to the northeast, Kuldana Formation connects to the Chorgali Limestone along the northern flank.

2. The Nurpur-Pithli Anticline

The Nurpur-Pithli Anticline appears from north of Nurpur Shahan, in the northeast of Islamabad. There, Chorgali Limestone flanked by Kuldana Fm emerges eastward under the south-facing thrust of the Margala Hills Anticlinorium. The anticline is continuously flanked by synclines of Kuldana Formation. At Saroha, it is fully integrated into the mountain front of the first ridge of the Margala Hills. Further to the northeast, at Pithli, the anticline is flanked by a syncline with steeply south dipping Chorgali Limestone. It is verging towards the northwest.

3. The Margala Hills Anticlinorium

The Margala Hills Anticlinorium forms the first ridge of the Margala Hills north of Islamabad. It is built by multi-vergent folds of the Margala Hill Limestone and Lockhart Limestone. Towards Nilan and Kharian valleys in the north, it is flanked by a syncline with Kuldana Formation in its core. The Margala Hills Anticlinorium continues beyond Shah Allahditta in the west of Islamabad. The internal structure of the anticlinorium changes very rapidly along the strike. The Margala Hill Anticliorium was investigated along the following traverses.

A. The Shah Allahditta -Islamabad Segment

Shah Allahditta village is located in the west of Islamabad on Murree Formation comprising mainly sandstone and siltstone. Here the relationship between the Murree Formation of the northern Potwar and calcareous sediments of the Indo-Pakistan could be investigated (Figure 3). The sandstone of Murree Formation dips 333°/33° and is concordantly overlain by 20 m thick Kuldana Formation, thus indicating an overturned sequence. It is in turn overlain by steeply folded Jurassic limestone. From the north, it is overthrust by Margala Hill Limestone. They are bordered by an EW trending valley, filled with dark brown weathered shale of Patala Formation. Lockhart Limestone occurs in anticlinal position further in the north. Between Shah Allahditta-Islamabad segment Mesozoic rocks thrust over Tertiary rocks, most likely Kuldana Formation.

B. The Islamabad-Shahdara Segment

In the north of Islamabad near Daman-e-Koh, on the road to Nilan valley, a triple crested anticline of Jurassic oolitic limestone is exposed. From Islamabad side at the first hairpin bend of the road, Hangu and Margala Hill Limestone are wedged in a synclinal position. The anticline is overturned to the south and the Mesozoic limestone crops out at various places thrust upon Kuldana Formation (Appendix 2, Cross-section A-A'). The hanging wall towards the north is made of Lockhart Limestone with Hangu Formation appearing in places. Usually, the contact is faulted, displaying disharmonic folding. Further to the N of Daman-e-Koh, the Lockhart Limestone is folded into a syncline with a small anticlinal fold in its core (Cross-section A-A'). To the north follows steeply south dipping 20 m thick discontinuous layer of Patala Shale. In this layer, an important fault is running with a throw towards the north against south facing and folded Margala Hill Limestone. This Margala Hill Limestone is overturned towards the north in a disharmonic way over Chorgali Limestone, which in turn is folded in north facing recumbent folds. This leads to a widespread distribution of Chorgali Limestone along the north slope of the first ridge of the Margala Hills towards the Nilan valley and further continuing to the east. These conditions remain unchanged for Islamabad and Shahdara segment (Cross-section C-C').

C. The Shahdara-Bashkoli Segment

About 1 Km northeast of Shahdara the southern flank of the Margala Hills Anticlinorium is in normal contact with a syncline filled by Kuldana Formation that separates it from the eastwards rising Nurpur-Pithli Anticline. The latter is incorporated into the mountain front of the Margala Hills east of 73°10' E (in west of Baroha) (Cross-section D-D').

The Margala Hills Anticlinorium fades into a single anticline of presumably Margala Hill Limestone and east of Pholira, (3 Km SW of Nilan Photu) a wide distribution of Chorgali Formation can be observed. At Dheri Rakhala, the anticline is composed of Margala Hill Limestone. To the south, Chorgali Formation is found at the flank leading to the Kuldana Formation of the syncline between Margala Hills Anticlinorium and the Nurpur-Pithli Anticline (Cross-section D-D'). To its north, a number of folds are added to the Margala Hills Anticlinorium. North of Dheri Rakhala, widespread folded Chorgali Formation occurs serving as connecting structures. The Nilan valley hosts a syncline with Kuldana Formation and extends to Kharian valley in the east.

East of 73°10' E, this syncline occurs near Jhangri. Between Gado and Kimbi (Cross-section EE') it is met along the ridge 1,000 m north of Kimbi and continues eastward to the north of Gharaga.

4. The Dalhor-Gambhir Anticline

The second ridge of the Margala Hills occurs in the north of Nilan valley and is referred to as Dalhor-Gambhir Anticline. At Dalhor, Jurassic rocks are tectonically overlain by west dipping Tertiary limestone with abundant Nummulites. Southward, the Jurassic rocks are in turn in steep tectonic contact with folded Chorgali Limestone occupying the floor of Nilan valley. West of Gokina, outcrops of more resistant limestone force the Nilan River into a southward bend. These limestones have been tentatively assigned to the Margala Hill Limestone. From Gokina onwards to the east, Kuldana Formation forms the valley floor, indicating an eastward plunge of the syncline axis. Parallel towards the north, the Jurassic limestone continuously reduces its thickness below the thrust of Tertiary limestone until it disappears east of 73°08'30" E (approx. 1 Km W of Nila Bhotu). Near Nilan Bhotu, Kuldana Formation is steeply dipping (315°/85°) and exposed along the road. To the north is Tertiary limestone, dipping northwest (323°/34°). To the south, strongly recumbent folded Chorgali Formation occurs (Cross section C-C’).

The Dalhor-Gambhir Anticline yields bundle of folds towards Gambhir valley of Eocene rocks of Margala Hill Limestone and Chorgali Formation. At Phalagali, the northern front of this fold bundles appears as an overturned anticline of assumed Margala Hill Limestone. In the north of Phalagali, a very steep anticline of Maragala Hill Limestone with Patala Shale in the core emerges from the

Chorgali Formation west of Lora. This anticline, the northern Phalagali Anticline, is clearly overturned to the north. After 3 kilometers westwards it disappear under the Chorgali Formation. Only a small slice of Margala Hill Limestone continues further towards Rupper.

5. The area northwest of the Lora Synclinorium

The Lora Synclinorium is occupied by Chorgali Formation with deeper synclines of Kuldana Formation. In its northwest, Jurassic rocks form a foldbelt. Within this foldbelt at least two anticlines occur. The cores of these anticlines are built in Jurassic limestone. One such anticline is at the bridge west of Rupper across the Katha Rupper and the second one is north of Kohala. These folds are verging in different directions.

At the confluence of Haro Dhund with the Haro Karralan, Paleocene Lockhart Limestone and Patala Shale are folded in a synclinal position between the above-mentioned Jurassic anticlines at Kohala in the south.

Jabri Bazar is within a syncline with extremely reduced Chorgali Formation and Margala Hill Limestone at its northern flank, which is in faulted contact to the recumbent folds of Jurassic and Cretaceous limestone of Mount Dubran. The position of the entire syncline with respect to the Mount Dubran is of completely different structural pattern and it seems to be the result of a significant fault.

6. The Mount Dubran fold and thrust structure

Dubran village is positioned in the core of a north verging anticline with Jurassic limestone in its core. This anticline is overturned and its lower flank can be observed at the bridge north of Jabri, where Jurassic dolomite limestone is followed by a few meters of black Chichali shale and soft and brown weathering Lumshiwal sandstone. The youngest sediments are Lockhart limestone (Figure 4). This anticline is comprised of a number of south-facing recumbent folds, mostly of Jurassic limestone and dolomite, also including Lumshiwal sandstone and Chichali shale and possibly Kawagarh limestone. In the summit region, these folds are thrust by partly overturned Cretaceous limestone and (?) Jurassic dolomite. The direction of the thrust is not yet clear but there are a number of indications that it comes from the north and can be seen in the context of the nearby Nathiagali Fault.

Discussion

The structural and stratigraphic investigation reveal that molasse sediments of Murree Formation of Northern Potwar have been incorporated into the southern part of the Hazara Fold belt, formed by calcareous sediments of the Indo-Pakistan Plate. These highly folded sediments have been dissected by Nathiagali and Murree faults. The Margala Hills Anticlinorium is an important structural element, which runs between Shah Allahditta and Daleh and is built of Jurassic rocks in the core. These older rocks extend till Shahdara in the east. The anticlinorium is overturned to the south. The core of the anticlinorium is generally thrust on Kuldana Formation.

At Daleh, Chorgali Formation of the Margala Hills Anticlinorium is in contact with Kuldana Formation of the syncline in the south. Further to the northeast, this Kuldana syncline is an integrated part of a system of folds that also includes the Nurpur-Pithli Anticline. This anticline in turn develops out of the Kuldana Formation east of Islamabad at Nurpur Shahan, and has to be regarded as the normal basement of the Potwar Plateau. Between Shah Allhditta and Murree along the southern margin of the Margala Hills Range, no indication of a major fault like MBT was found. The structure of the mountain front is dominated by south verging Mandla-Tret anticline.

Murree Formation of the northern Potwar Plateau always is underlain by Kuldana Formation of the southern Hazara. Thus, this area may be regarded as a parautochtonous structural belt rooted at the northern fringe of the Potwar Plateau. It has been thrust in a piggyback style very similar to the structures found in seismic sections by Lillie et al. (1987) and Baker et al., (1988).

The Main Boundary Thrust west of Muzaffarabad is most likely a transform fault, west of which the sediments overlying the basement of the Indian Plate are detached, folded, and thrusted. It is assumed an analogue to the transform faults bordering the re-entrants of the Western Fold belt (Bannert et aI., 1992a, 1992b). The thrusts developed during the process of relative southward propagation of the detached sediments, in response to Eocene collision between the Indian Plate and Kohistan Arc at the site of Main Mantle Thrust (MMT). The speed and direction of this northward movement is different from the southwestward movement of the Kashmir Himalaya to the east of the Jhelum Re-entrant.

Three detachment horizons have been identified in the area under investigations. One is within or at the base of the Jurassic Samana Suk Limestone and a higher one in the Kuldana Formation. Further to the north, a very important detachment horizon of regional importance is within or at the base of the Hazara slates. Its frontal thrust is the Nathiagali Fault.

This discussion led to the following:

1. Generally, there is consistency in the stratigraphic succession of the area.
2. No regional thrust fault was observed.

3. Faults are generally reversed in nature and follow the general NE-SW strike.
4. Contrary to the general belief, there is no persistent fault between the Mesozoic-Cenozoic rocks and the overlying molasse.
5. Multi-vergent folds dominate the area.

These factors show that on regional scale, the contact between Mesozoic- Cenozoic and Miocene molasse sediments is concordant and the MBT (Main Boundary Thrust) does not occur at least in the area under investigation.

Petroleum Prospectivity

The Kalachitta-Margala Range is a hilly range built of outcropping rocks of Peshawar-Hazara basin in the north and Kohat-Potwar Basin in the south. Klachitta-Margala Hills Range and Peshawar-Hazara Basin are dominantly covered by Paleocene-Eocene rocks with Jurassic rocks in the core of few outcrops. The Kohat- Potwar Basin in the south has thick cover of molasse sediments. Locally Eocene rocks are exposed, generally, along the faults. The area is structurally complex and characterized by imbricate thrusts.

There are good indications of presence of active petroleum system elements in the area. TOC results of Chichali shales (Late Jurassic to early Cretaceous) from outcrop samples show favourable organic richness of 0.4-2.7% (Table 2). TOC values in the exposed Paleocene age formations are reasonably fair to good e.g. in Hangu Formation 0.5%, Lockhart Limestone 0.13-0.34% and in Patala Formation 0.2-0.4%. In addition, Margala Hill Limestone (Eocene) and shale has also fair to good TOC of 0.2-0.6%. Extractable organic matter (EOM) in Chichali, Hangu and Margala Hill formations suggests reasonably good source rock potential. The analyzed samples for source rock evaluation were collected from exposed sections of the above-mentioned formations and hence reflect a somewhat weathered version of the actual source potential. Reported oil seepages at Golra (Figure 5) and Balochistan House, Islamabad (Table 3) are encouraging signs of petroleum prospectivity of the area. The Prist/Phy ratio for oil seepages from Balochistan House suggests derivation of the sample from source rock deposited in anoxic marine environment. Nevertheless, one would tempt to interpret Balochistan House Seepage to be derived from more mature source rock than Golra Seepage sample, assuming derivation from the same source rock and similar level of biodegradation. The bulk composition data (Table 3), however, cannot help to understand source, maturity or post seepage influence on these seeps. Gas seepages have also been reported from Peshawar Basin.

In addition to the source rock potential, reservoir potential is present in Lockhart Limestone and in Hangu formations. Furthermore, sands of Lumshiwal Formation (Cretaceous), Datta Sst. (Jurassic) are proven reservoir rocks in the adjoining Kohat and Potwar basins. Shaly formations as well as intra-formational shales are present in the Jurassic, Cretaceous and in Paleocene rocks, in addition to the

Jatta gypsum and Kuldana shale of Eocene age. These formations can act as seal for the underlying potential hydrocarbon reservoirs as shown in Table 1.

Discoveries along the Kalachitta-Margala Hill foothills at Bhal Syedan, Mela, Makori, Manzalai, and Chanda confirm the generation, migration and accumulation of hydrocarbons.

Interpretation of data suggests that Kalachitta-Margala Hill Range is not separated from the adjacent basins by a regional fault like MBT. On the other hand, the Hill range appears to be a regional fold, characterized by southward overturned Margala Hill Anticlinorium that forms the mountain front of the south Hazara Fold Belt. The Peshawar-Hazara Basin and Potwar-Kohat Basin are geologically integrated and situated on the northern and southern margins of the said fold. This leads to the conclusion that hydrocarbons generated in the kitchen areas might have migrated to the folds (Figure 6). However, due to structural complexities, identification of potential traps in the subsurface will be an exploration challenge.

Recommendations

To understand the nature of the MBT in the western Himalayas, the MBT around Islamabad and west of Muzaffarabad needs investigation in the broader context of Himalayan tectonics (India and Nepal).

The widespread north vergent folds along the Kalachitta-Margala Hills Range mountain front require detailed investigation.

Geochemical studies and reservoir characterization are required to assess the hydrocarbon potential of the region.

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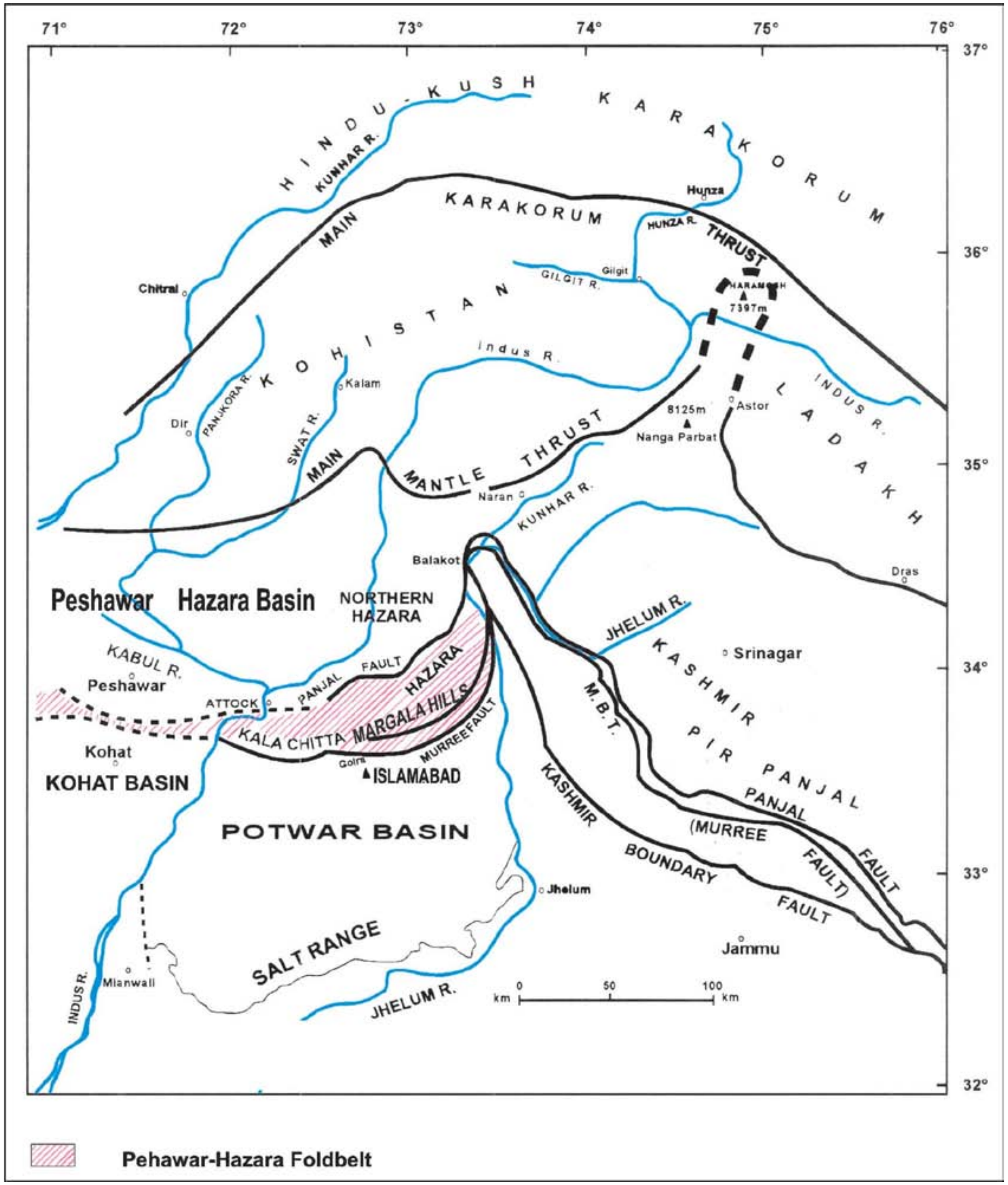


Figure 1. Major structures of the western Himalayas and location of the Kalachitta-Margala Hills Range (modified after Ghazanfar et al., 1990).

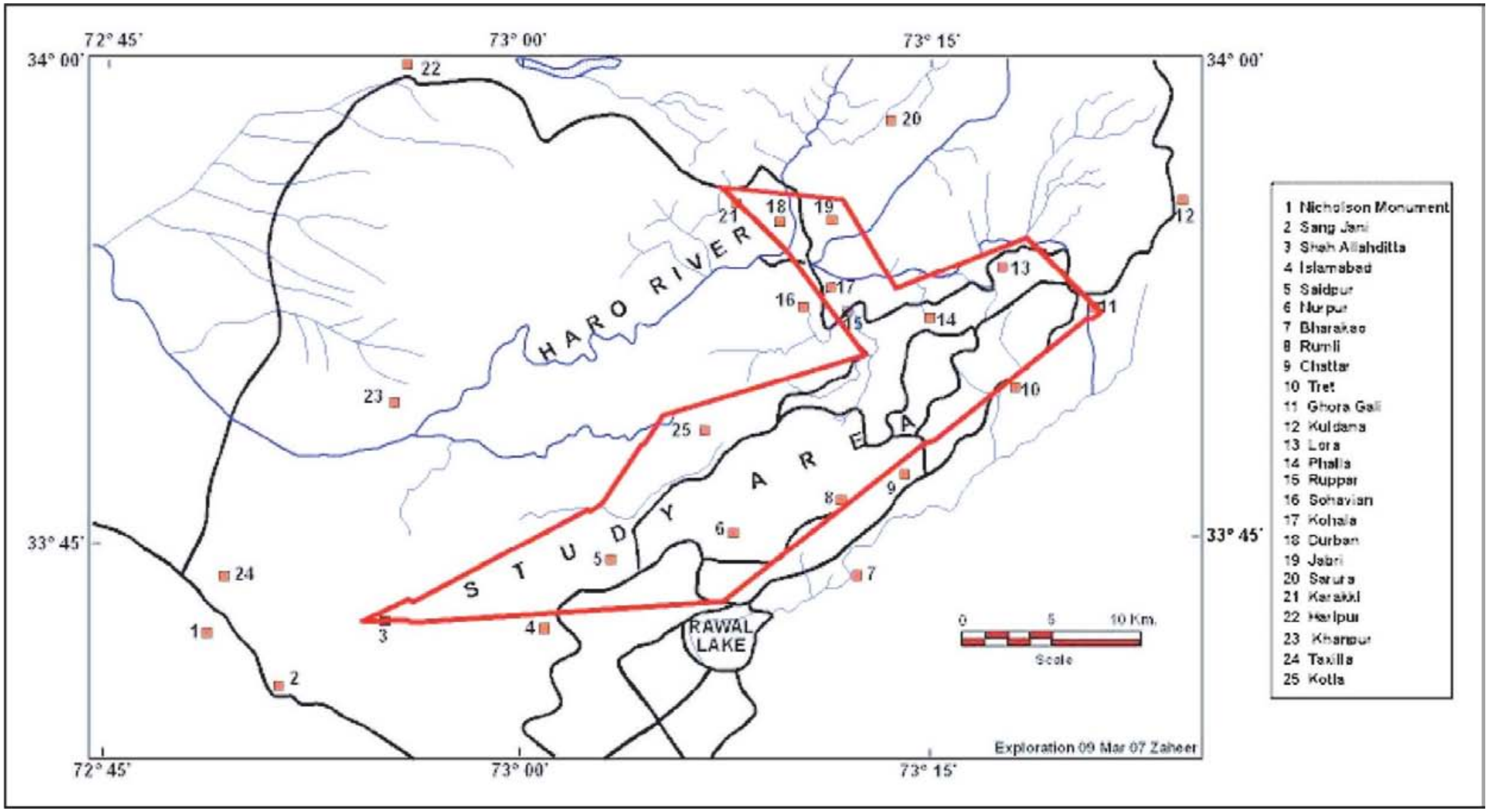


Figure 2. Sections visited in the eastern segment of the Kalachitta-Margala Hills Range.

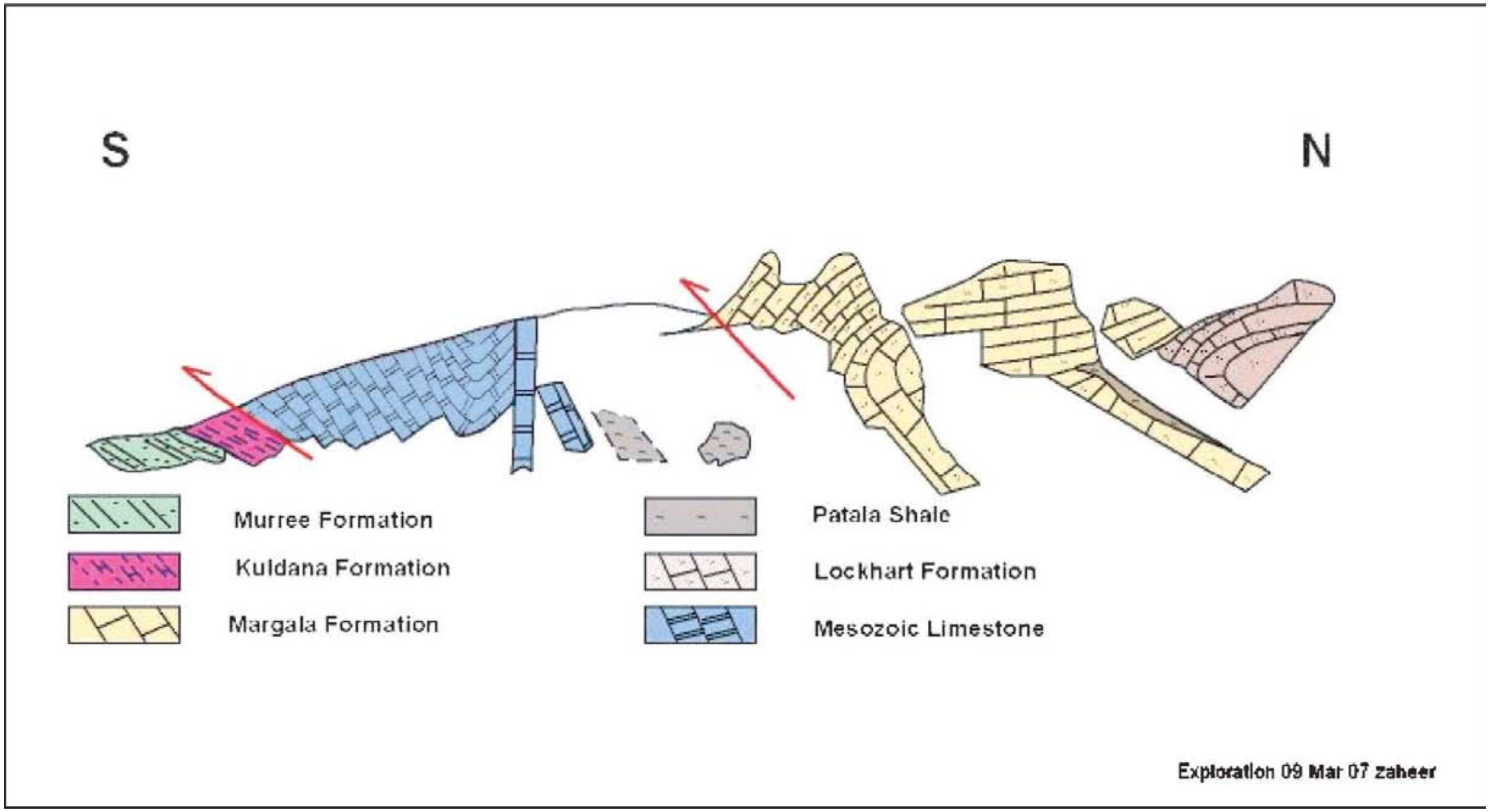


Figure 3. Cross-section of the southern Margala Hills Anticlinorium north of Shah Allahditta. Not to scale.

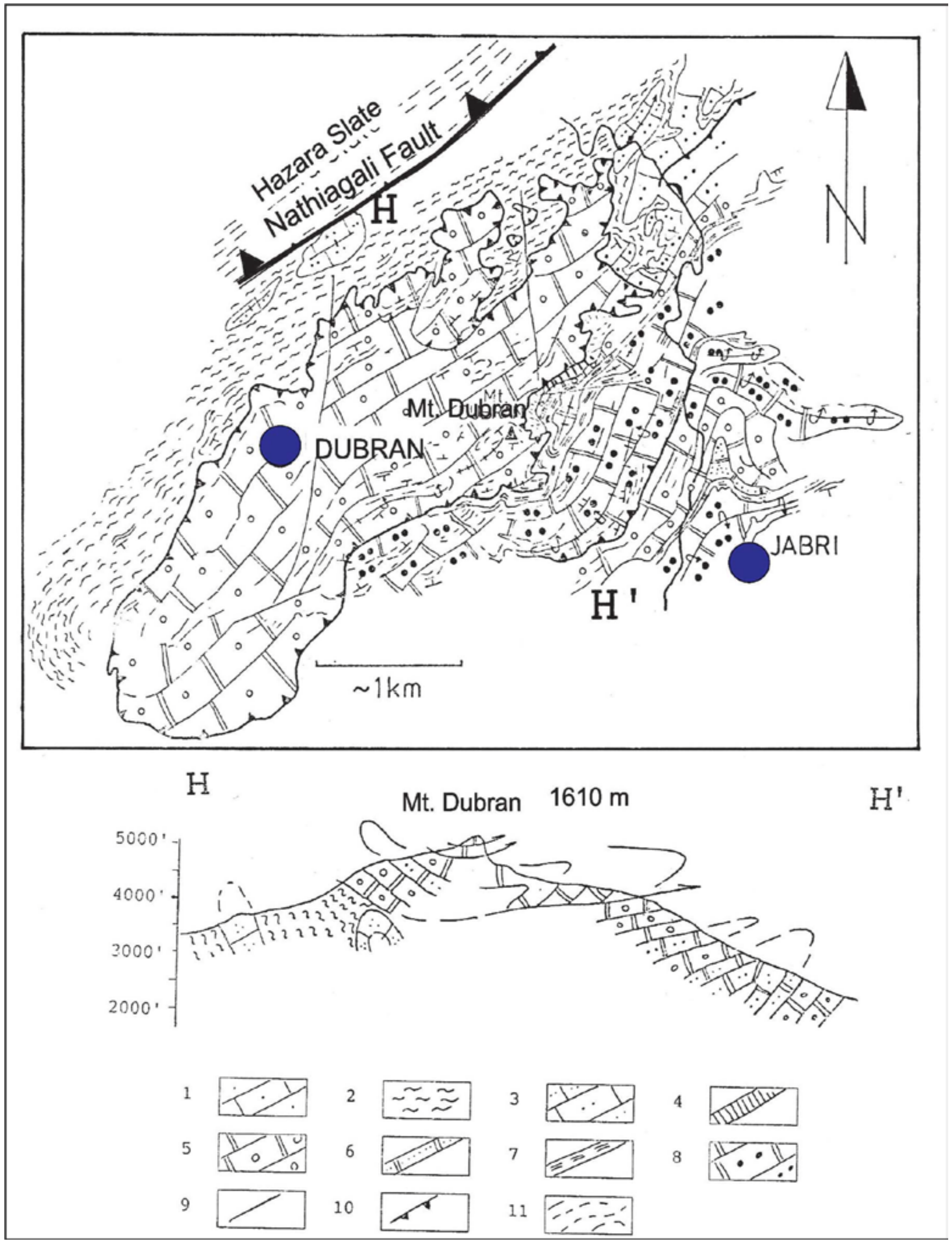


Figure 4. Geological sketch map of the Mount Dubran.

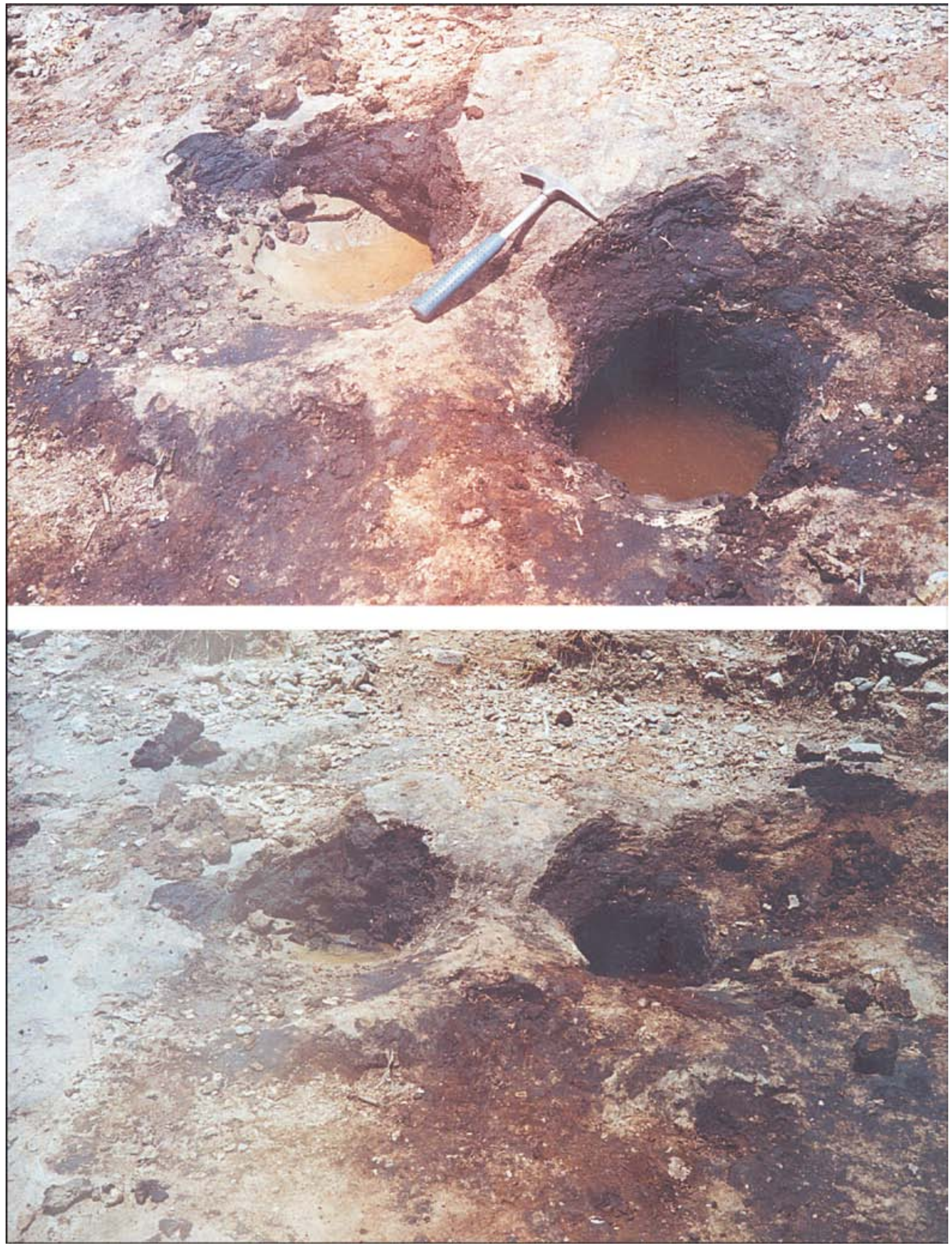


Figure 5. Golra Seepage, west of Islamabad.

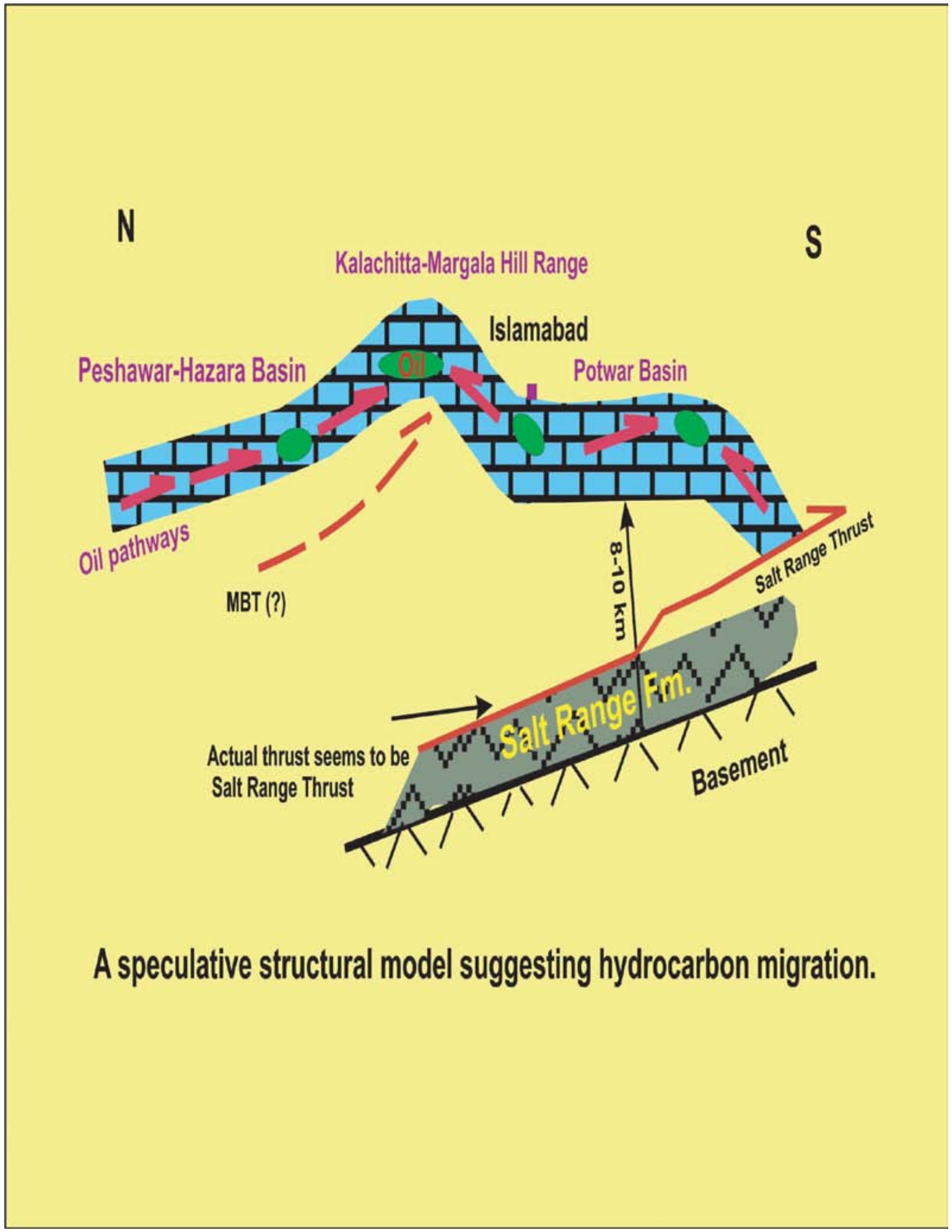


Figure 6. A speculative model shows possible hydrocarbon migration mechanism in Peshawar-Hazara Basin, Kalachitta-Margala Hills Range, and Kohat-Potwar Basin.

AGE	FORMATION	LITHOLOGY	DESCRIPTION	PETROLEUM SYSTEM			REMARKS
				SOURCE	RES	SEAL	
Miocene	MURREE		Sandy shale, siltstone, sandstone, conglomerate, fossiliferous limestone at the base.				Detailed tectonic study is not carried-out.
Early - Middle Eocene	KULDANA		Variegated, multicoloured and maroon to magenta silt and shale, and yellowish to blusih grey, marly, well banked limestone and cellular limestone.				
Early Eocene	CHORGALI (LORA)		Alternating well banked limestone and brownish to greenish marl. The limestone has chert lenses in places.				Reacts with folding to tectonic pressure. Often recumbent folds.
Early Eocene	MARGALA HILL LIMESTONE		Well banked, usually dark grey but light grey weathering limestone, occasionally nodular; massive and cliff-forming.				Alveolina and Nummulites atacicus are the fossils to separate Margala Hill limestone from Lockhart limestone.
Late Paleocene	PATALA (KUZAGALI)		Medium to dark brown shale with marly limestone layers.				Under tectonic pressure the shale becomes phyllitic.
Middle Paleocene	LOCKHART (MARI LST.)		Well banked, usually dark grey and dark grey weathering limestone, occasionally nodular inliers; massive and cliff-forming; caves.				Small Nummulites and other fossils, no specific fossil for field identificiation can be observed.
Early Paleocene	HANGU		Oxidized sandstone, white clay, iron-crusts, rusty weathering limestone, pisolitic gossan.				Often tectonically reduced.
Early - Middle Cretaceous	DUBRAN KAWAGARH CHANALI		Well banked limestone with frequent layers of oyster, shallow water indications. Dark brown weathering limestone, partly dolomitic. Whitish-blue weathering, well banked limesotne, rich in sea urchins, locally conglomerates, dolomitic in palces.				
Early Cretaceous	LUMSHIWAL (GIMUL)		Dark brown weathering thickly banked sandstone of dark grey to black colour with an occasional greenish tint, glauconitic.				
Late Cretaceous	CHICHALI (SPITI)		Black shale, thinly bedded, brown, often rusty weathering.				
Middle-Late Jurassic	SAMANA SUK (SIKHAR)		Well banked limestone, partly oolithic, often rich in fossils, yellowish tints, partly dolomitic.				Usually intensively folded.

(Modified after Latif 1968 & Shah 1977)

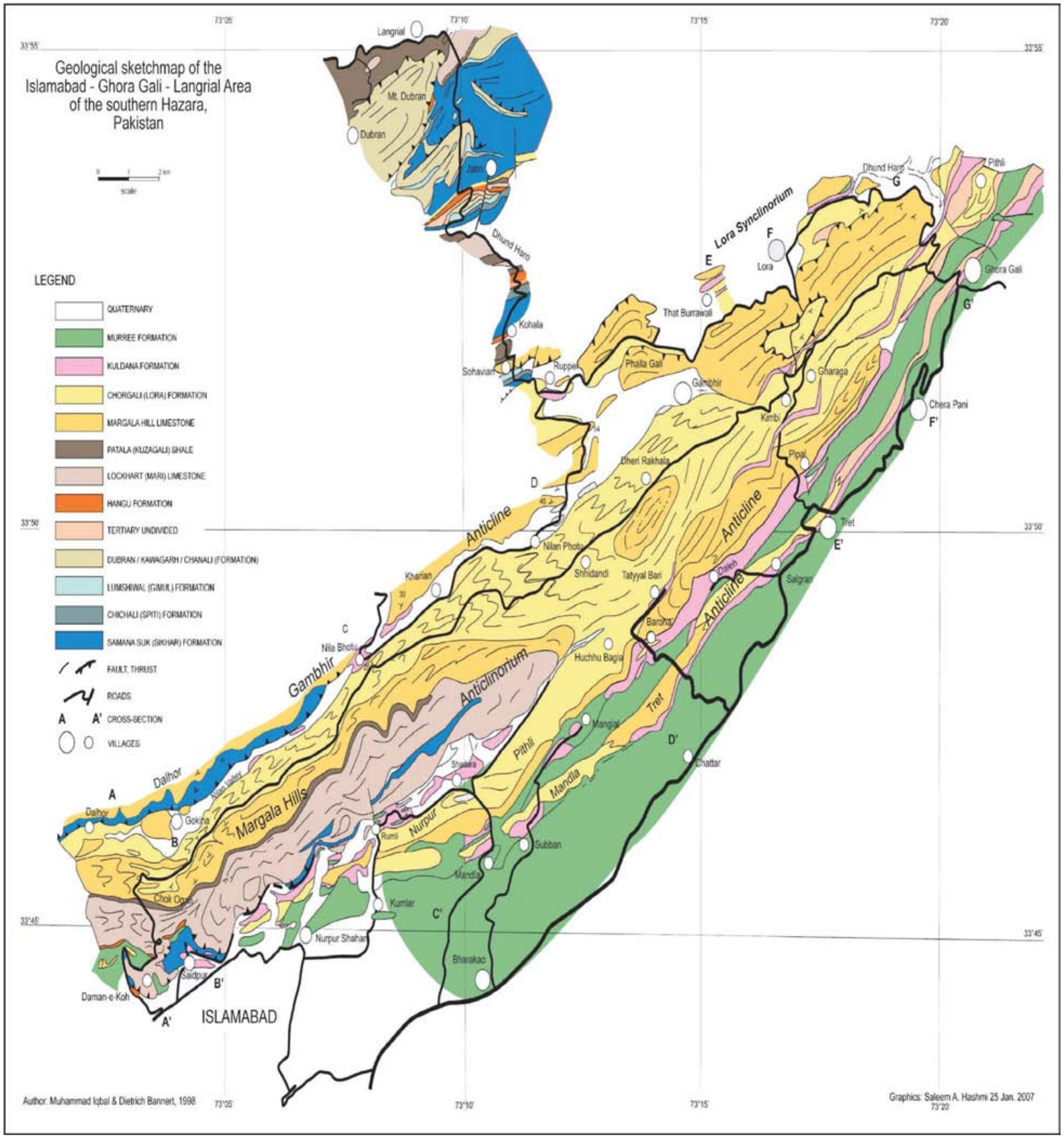
Table 1. Stratigraphic Succession of the Kalachitta-Margala Hills Ranges

Formation	Lithology	TOC %	G.P.	HI	EOM ppm	EXT / TOC	SAT. HC %	ARO BC%	NSO. %
Margalla Hills Lst.	Shale	0.49	0.2	41	-	-	-	-	-
Margalla Hills Lst.	Limestone	0.17	-	-	-	-	-	-	-
Margalla Hills Lst.	Limestone	0.26	-	-	-	-	-	-	-
Margalla Hills Lst.	Dark Limestone	0.34	-	-	-	-	-	-	-
Margalla Hills Lst.	Dark Limestone	0.57	-	-	312	55	39	36	25
Chichali Fm.	Shale	1.48	<0.1	7	15	1	-	-	-
Chichali Fm.	Black Shale	0.41	-	-	-	-	-	-	-
Chichali Fm.	Black Shale	2.68	<0.1	4	28	-	-	-	-
Chichali Fm.	Black Micaceous Sandy Shale	3.93	-	-	966	27	6	52	32
Hangu Fm.	Siltstone	0.48	<0.1	20	-	-	-	-	-
Hazara Fm.	Shale	0.4	-	-	-	-	-	-	-
Lockhart Lst.	Limestone	0.23	-	-	-	-	-	-	-
Lockhart Lst.	Dark Shale	0.34	-	-	-	-	-	-	-
Lockhart Lst.	Dark Limestone	0.13	-	-	-	-	-	-	-
Patala Fm.	Shale	0.25	-	-	-	-	-	-	-
Patala Fm.	Shale	0.25	-	-	-	-	-	-	-
Patala Fm.	Shale	0.4	<0.1	25	-	-	-	-	-
Upper Cretaceous	Dk. Grey to Black Mieritic Limestone	0.23	-	-	-	-	-	-	-

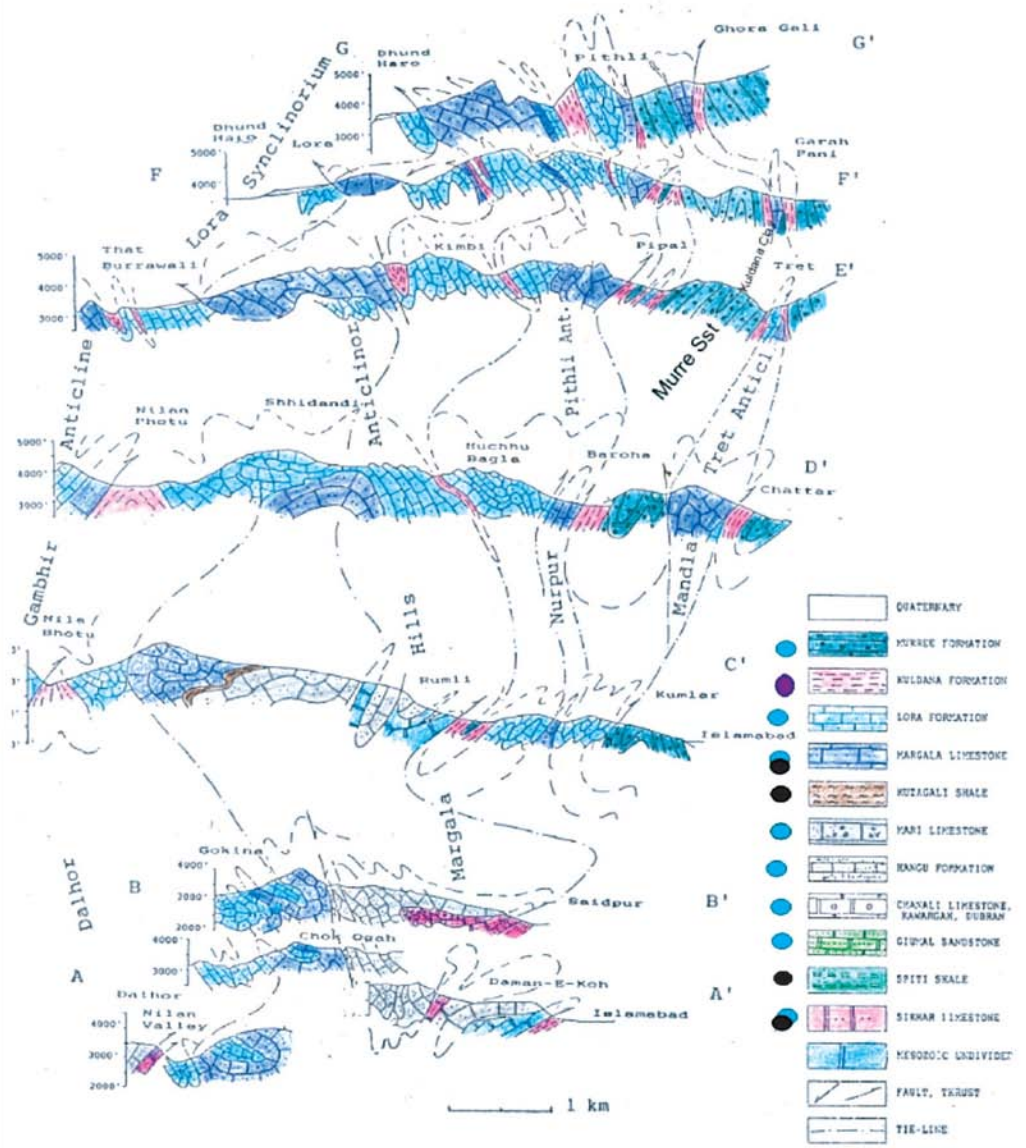
Table 2. Geochemical Data of Surface Rock Samples from Hazara and Kalachitta Ranges.

Name of Seepage	Depth (m)	Lithology	SAT. HC %	ARO BC%	NSO. %	Prist/Phy	Phy/n C18	OEP-29
Golra Seepage	Surface	Gypsum	52	40	8	-	-	-
Golra Seepage	Surface	Oil seepage	39	42	19	-	-	-
Golra Seepage	Surface	Oil seepage	32	46	22	-	-	-
Baluchistan House	100	Oil seepage	70	26	4	1.5	0.3	1.09

Table 3. Geochemical Data of Oil Seepages



Appendix 1. Geological sketch map of the Islamabad-Ghoragali segment.



Appendix 2. Geological cross-sections of the Islamabad-Ghora Gali Area.

● Potential source rock ● Potential reservoir ● Seal rock

Appendix 2. Geological cross sections of the Islamabad-Ghoragali segment.