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Structural Observations of the Margala Hills, Pakistan and the Nature of the Main Boundary Thrust

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ABSTRACT

The area of the Margala Hills between Islamabad in the west and Ghora Gali in the east has been investigated to reveal the structure of the tectonically important Main Boundary Thrust of the central and western Himalayas. The existence of the Main Boundary Thrust is an essential factor in the assessment of the hydrocarbon potential of the Hazara foldbelt and the adjoining Peshawar Basin.

It has been found that the basal series of the molasse sediments (Murree Formation) are at many places in normal stratigraphic contact with the underlying rocks of the mostly calcareous Indo-Pakistan Plate sediments. Within these sediments folds developed that can be followed over several tens of kilometers. The structural style including the orientation of the fold axis plane changes very rapidly along the strike.

The investigation did not reveal any indication of a major thrust or fault in the area of the southern and frontal part of the Hazara foldbelt. Therefore, the existence of the Main Boundary Thrust in this area is negated.

INTRODUCTION

The area under investigation is a part of the Lesser Himalayas, a subdivision of a larger Himalayan Province and is situated between Latitude 33°30'-34°00'N and Longitude 73°.00'-73°.23'E on Survey of Pakistan sheets No.43C & 43G. The area with Karakki in the north, Ghora Gali in the east, and Islamabad in the southwest is given in Figure 1. The available literature and the study of LANDSAT-MSS imagery show that the area is lobe shaped and Nathiagali Fault occurs in its north and Murree Fault occurs in its south and east, respectively (Figure 2).

The present study is based on the interpretation of selected aerial photographs, acquired from the Survey of Pakistan on 1:40, 000 scale. The interpretation was confined to the structural aspects which was followed by a fieldwork of 23 days during the period from March 20, 1994 through June 28, 1994.

To understand the nature of the Main Boundary Thrust (MBT), a significant structural element on the geological map of the area, several traverses were made across and along the fault. The geological observations made in the field were correlated with the information of air photo interpretation and were plotted on 1:25,000 topomap and a geological map of the area was prepared (Appendix 1).

The study has been designed in a way to address the problems related to the complex structures of the area with special reference to the Main Boundary Thrust (Figure 3) and to come up with a precise tectonic model of the area.

PREVIOUS WORK

The earlier geological investigation in the Hazara area has been carried out by Waagen & Wynne (1872), who had published a geological report about the stratigraphy of a small area in the vicinity of Abbottabad.

Middlemiss (1896) prepared the geological map of the area extending from Black Mountains on the west to Kunhar River in the east. He introduced the term Main Boundary Thrust.

Wadia (1931) used the term "syntaxis" for the sharply bending mountains around Muzaffarabad. He further reported two more or less parallel and persistent thrust faults which extend from the Jhelum River to the Ravi River (Calkins et al., 1975). The inner thrust which he termed Panjal Thrust served as a basal sliding plane for a large Kashmir Nappe, which brings southward slates and schists of the Purana Series (Precambrian) from the central mountains over rocks of Carboniferous to Eocene age. The outer thrust was called the Murree Thrust by Wadia (Calkins et al., 1975), is a reverse fault which brings Carboniferous through Eocene age sediments southward over rocks of the Murree Formation.

Pascoe (1963) used the term Great Boundary Fault for the Main Boundary Fault of Middlemiss (1896) and he believed it to mark the limits of deposition of the younger molasse sediments. However, Pascoe (1963) was convinced that the term Boundary Fault is a misnomer. Its reason was that the term Main Boundary Thrust was already used in a sense that to the north of that fracture no molasse sediments occur but later on molasse sediments were reported from various parts of the area.

Latif (1968) published a report accompanied by a geological map of southeastern Hazara, which is a great contribution in understanding the stratigraphy of the area. Calkins et al. (1975) carried out detailed structural investigations in the Hazara. They divided the area into three structural blocks separated from each other by Panjal, Murree-, and Darband faults. These blocks are Hazara-Kashmir Syntaxis, Western Arc, and Indus Re-entrant.

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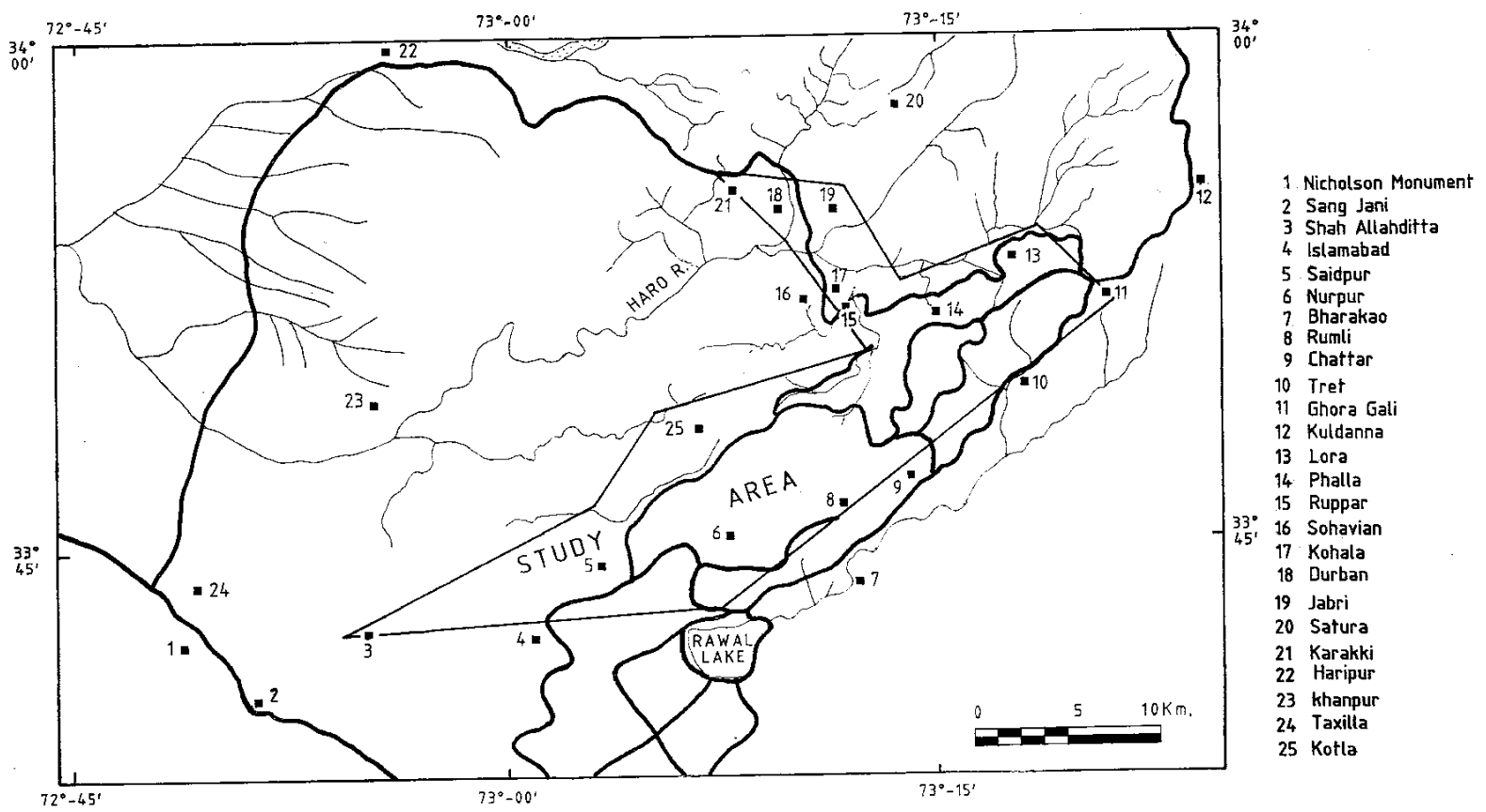


Figure 1- Location map of current investigation.

Calkins et al., (1975) were of the opinion that on the eastern limb of the Hazara-Kashmir syntaxis the Murree-, and Panjal faults are steeply dipping reverse faults. whereas on the western limb of the syntaxis, these are vertical north of Balakot.

Ghazanfar et al., (1990) gave details about the structural styles and tectonic events of the Hazara area.

It is generally agreed upon that the Main Boundary Thrust is a regional fault which separates the hill ranges of Kala Chitta and Margala from the Kohat-Potwar Plateau. In other words, it marks the tectonic contact between the Mesozoic shelf sediments of the Indian Plate lying tectonically over the molasse sediments of the foreland basin (Kohat-Potwar Plateau).

However, our study reveals that the area under investigation has been deformed by open, diverging fan-shaped folds arranged in a sub-latitudinal fashion. These folds are generally north verging in the northeast and south-verging in the southwest and there is relatively continuity in the stratigraphic succession between Murree Formation and the underlying older rocks.

GEOLOGY

The Main Boundary Thrust

The area investigated comprises part of the Main Boundary Thrust, the southernmost thrust of the Himalayan mountain ranges. In the central and eastern portions of the collision zone, in India and Nepal, it 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. The uplift of the Himalaya is attributed to the buoyancy of the doubled sialic crust over the mantle material (Gupta & Narain, 1967; Kono, 1974; Choudhury, 1975; LeFort, 1975; Mattauer, 1975; Powell & Conaghan, 1973). There, along the Main Boundary Thrust (MBT) the metamorphic rocks are thrusted above Siwalik rocks.

In Pakistan, the MBT can be observed to the east of the Jhelum Re-entrant, where it swings around to the west and then to the south roughly north of Muzaffarabad. Northeast of Islamabad, it gradually moves again to an east-westerly direction and is along the Murree Fault of previous workers.

There are, however, a few general considerations that make it difficult to follow the above mentioned scheme. These considerations are summarized as follows:

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 & Lillie, 1994).
3. The structure of northern Pakistan is not influenced by subduction and underplating below the 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 Re-entrant shows no indication of a bending and southwestward continuation of the MBT (Armbruster et al., 1978).

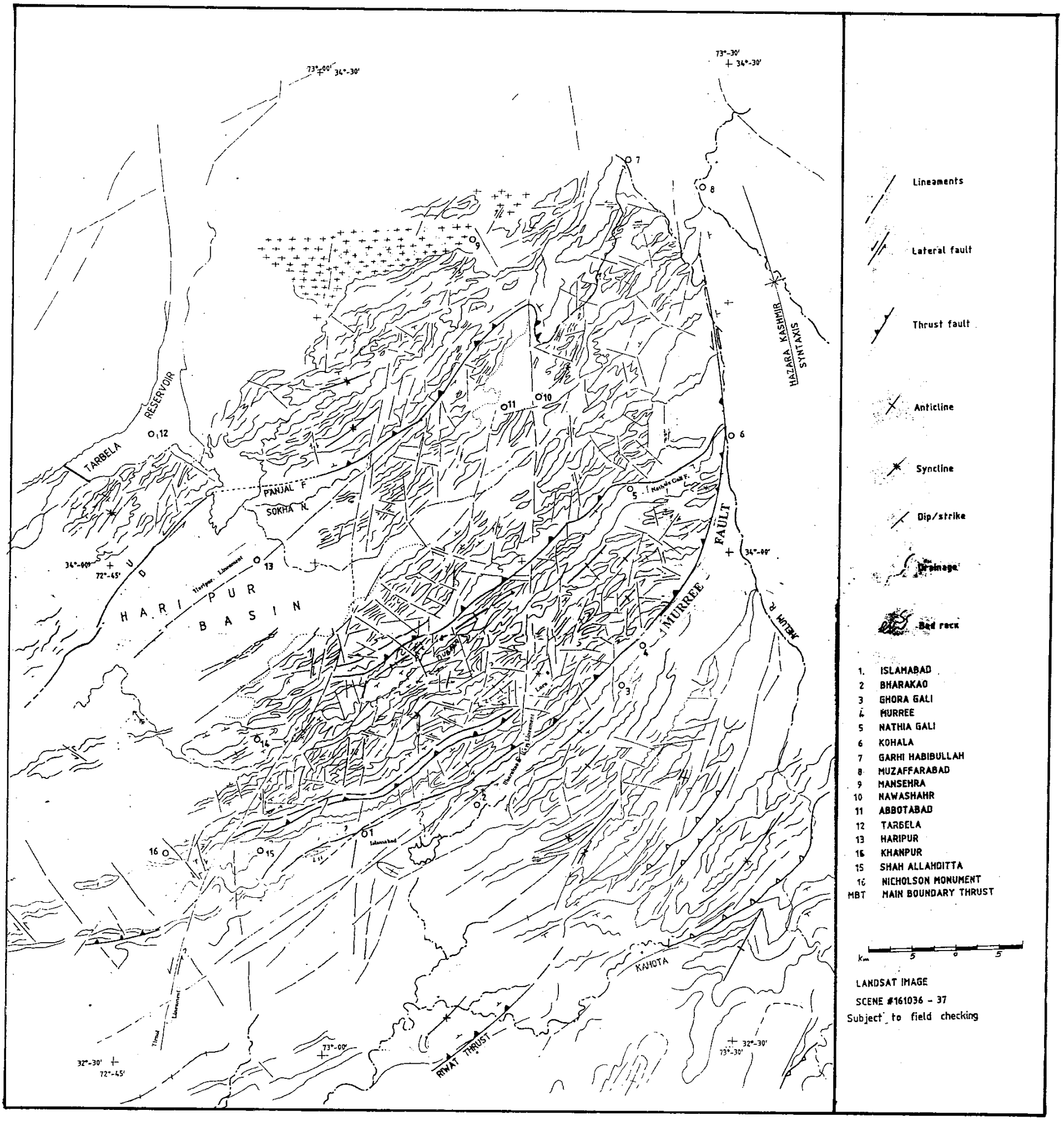


Figure 2- LANDSAT-MSS image interpretation of the southeastern Hazara, Pakistan (Iqbal, 1994).

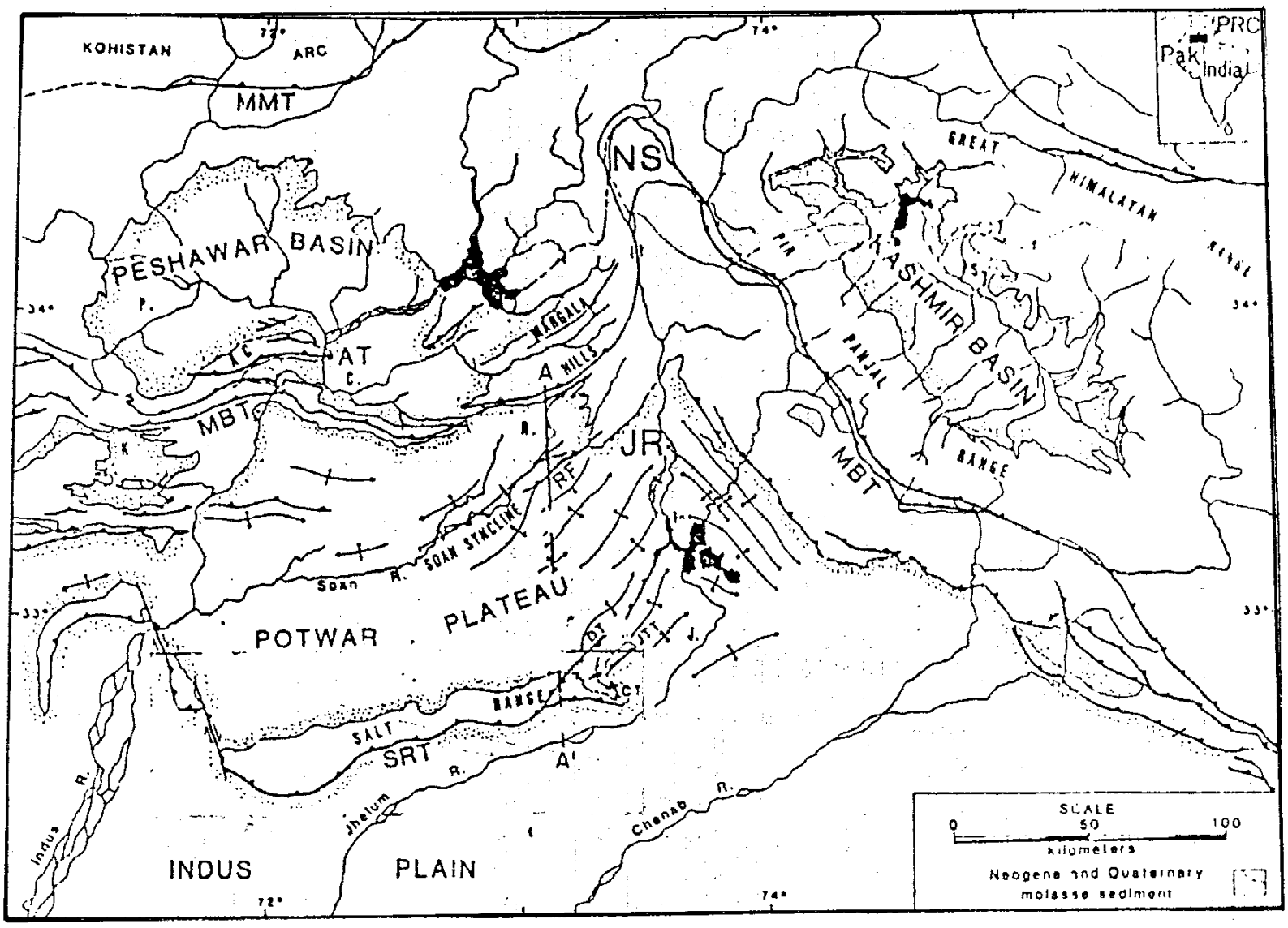


Figure 3- Map of northern Pakistan and the position of the Main Boundary Thrust (MBT) (from Burbank & Beck 1989).

6. In the area under consideration, the Murree Fault is difficult to define.

The present study focuses on the nature of the MBT, and does not agree with the concept of a far reaching regional thrust.

Stratigraphy

The stratigraphic succession encountered during the work starts with the Jurassic Sikhar Limestone and ends with the Miocene Murree Formation (Table 1 & 2).

Structure

The area between Islamabad and Ghora Gali is occupied in its southeastern part by rocks of the Murree Formation, which are of molasse nature. North of Islamabad and west of Ghora Gali, mostly calcareous sediments of Jurassic to Middle Eocene age occur. They belong to the shelf sediments of the northwestern Indian Plate. All the rocks are folded during the Himalayan orogenesis.

The calcareous rocks underlying the molasse are folded in narrow and elongated folds and fold-complexes. The description starts with the eastern folds. The more inward folds will follow. Generally, only the anticlines will be described, as the syncline fills very often are reduced to a few meters of younger rocks.

The Mandla - Tret Anticline

East of Islamabad and to the north of Bharakau, a narrow anticline comprising limestones of Early Eocene Lora Formation emerges from rocks of the Kuldana Formation. To the east, the anticline becomes more prominent and achieves increasing altitudes. From 600 m a.s.l. north of Mandla, it rises to 835 m near Tret and finally reaches 1520 m at Ghora Gali. The core of the anticline is made up of limestone of various ages. It is Lora limestone between Mandla and Tret. In Ghora Gali, along the road to Langrial it is Paleocene Mari Limestone(?), dipping 315°/48°. There, the limestone is severely tectonised.

Although the Mandla-Tret Anticline has strongly faulted contacts at Ghora Gali, it is important to notice that in the west at Mandla the core of Lora limestone is flanked on both sides by softer shales of Kuldana Formation. The Kuldana Formation of the southern flank at Mandla is concordantly overlain by the basal beds of the Murree Formation, comprising of nummulitic aggregates. The Kuldana Formation can be observed continuously along the southern (further on southeastern) flank of the anticline. To the north, a syncline of folded Murree Formation and Kuldana Formation exists. From Tret to the northeast, Kuldana Formation connects to the Lora limestone along the northern flank.

Table 1. Tertiary stratigraphic succession of the southern Margala Hills.

FORMATION (Age)	LITHOLOGY	REMARKS
MURREE (Miocene)	sandy shale, siltstone, sandstone, conglomerate, fossiliferous limestone at the base	its tectonic deformation is not included in this paper.
KULDANA (Early to Middle Eocene)	variegated, multicoloured and maroon to magenta coloured silt & shale, and yellowish to bluish grey, marly, well banked limestone and cellular limestone	
LORA (Early Eocene) (CHORGALI)	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. Shale reacts phyllitic near faults
MARGALA HILL (Early Eocene)	well banked, usually dark grey but light grey weathering limestone, occasionally nodular inliers; massive and cliff-forming	Alveolina and Nummulites atacicus are the fossils to separate Margala Hill limestone from Mari limestone
KUZAGALI (Late Paleocene) (PATALA)	medium to dark brown shale with marly limestone layers	Under tectonic pressure the shale reacts phyllitic
MARI LST. (Late Paleocene) (LOCKHART)	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 identification can be observed
HANGU (Paleocene)	oxidized sandstone, white clay, iron-crusts, rusty weathering limestone, pisolitic gossan	often tectonically reduced

The Nurpur-Pithli Anticline

The Nurpur-Pithli Anticline appears from north of Nurpur Shahan in the northeast of Islamabad. There, Lora limestone flanked by Kuldana Formation emerges eastward under the south-facing thrust of the Margala Hills Anticlinorium. Five km to the northeast, between Kumlar and Rumli, Margala Hill limestone forms the core of the anticline. Near Baroha, northeast of Chattar, the limestone is rather well bedded, massive and lacking typical Margala Hill limestone fossils (Alveolina, Nummulites atacicus). North of the anticline a thick sequence of Lora shale can be observed. The core of the next syncline to the north is represented by rocks of Kuldana Formation along the Tatyyal Bari valley. The anticline is continuously flanked by synclines of Kuldana Formation, only at places it diminishes due to faults. From Rumli to Baroha, the anticline raises very sharply from 720 m to 1,100 m within 9 km. At Baroha 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 Lora Formation. It is verging towards the northwest.

The Margala Hills Anticlinorium

The first ridge of the Margala Hills north of Islamabad is built by the multivergent Margala Hills Anticlinorium. It is accompanied in the north by a syncline filled by Kuldana Formation of the Nilan valley and the Kharian valley.

West of Islamabad, the Margala Hills Anticlinorium continues beyond Shah Allahditta. The internal structure of the anticlinorium changes very rapidly along the strike. It can be described best along several traverses. The traverses visited during the field work were connected by aerial photo interpretation.

Table 2. Mesozoic stratigraphic succession of the southern Margala Hills (after Latif , 1970 and Shah, 1977).

FORMATION (Age)	LITHOLOGY	REMARKS
CHANALI (Late Cretaceous)	well banked limestone with frequent layers of oyster, shallow water indications	
KAWAGARH (Cretaceous)	darkbrown weathering limestone, partly dolomitic	
DUBRAN (Cretaceous)	whitish-blue weathering, well banked limestone, rich in sea urchins, locally conglomerates, dolomitic in places	
LATE JURASIC (Early Cretaceous) (LUMSHIWAL)	dark brown weathering thickly banked sandstone of dark grey to black colour with an occasional greenish tint, glauconitic	
SPITI (Late Jurassic) (CHICHALI)	black shale, thinly bedded, brown, often rusty weathering	
SIKHAR (Middle to Late Jurassic) (SAMANA SUK)	well banked limestone, partly oolithic, often rich in fossils, yellowish tints, partly dolomitic	usually intensively folded

The Shah Allahditta - Islamabad Segment:

The Shah Allahditta area was briefly visited in order to understand the relationship of the Murree Formation rocks with the underlying calcareous rocks. The field and air-photo observations can be summarized as shown in Figure 4.

Shah Allahditta is located on Murree Formation comprising mainly sandstone and siltstone. It dips 333°/33°. Concordantly it is overlain by Kuldana Formation thus indicating an overturned sequence. The Kuldana Formation is approximately 20 m thick. It is in turn overlain by steeply folded Mesozoic, most likely Jurassic, limestone. From the north it is overthrust by Margala Hill limestone. These limestones are quarried. They are bordered by an W-E trending valley, where abundant dark brown weathering shale occurs, which has been tentatively assigned to the Kuzagali Formation. In the north, more massive limestone in anticlinal position can be observed. It was assigned to be Mari limestone.

From Shah Allahditta to Islamabad, Mesozoic limestones are thrusted over the Tertiary rocks, most likely Kuldana Formation. However, no further investigation has been carried out along this segment.

The Islamabad-Shahdara Segment:

The road from Islamabad to Nilan Valley exposes near Daman-e-Koh a triple crested anticline of Mesozoic rocks, containing Jurassic oolitic limestone in places. Wedged in a synclinal position are also Hangu rocks and Margala Hill limestone at the first hairpin bend of the road. 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 Mari limestone with some Hangu Formation appearing in places. Usually, the contact is faulted, displaying disharmonic folding.

Further to the north of Daman-e-Koh, the Mari limestone is folded into a syncline with a small anticlinal fold in its core (Cross-section A-A'). To the north follows Kuzagali shale in a discontinuous layer of maximum 20 m thickness. In this layer, which is usually dipping very steeply towards the south, 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 Lora limestone, which in turn is folded in north facing recumbent folds. This leads to a widespread distribution of Lora Formation rocks along the north slope of the first ridge of

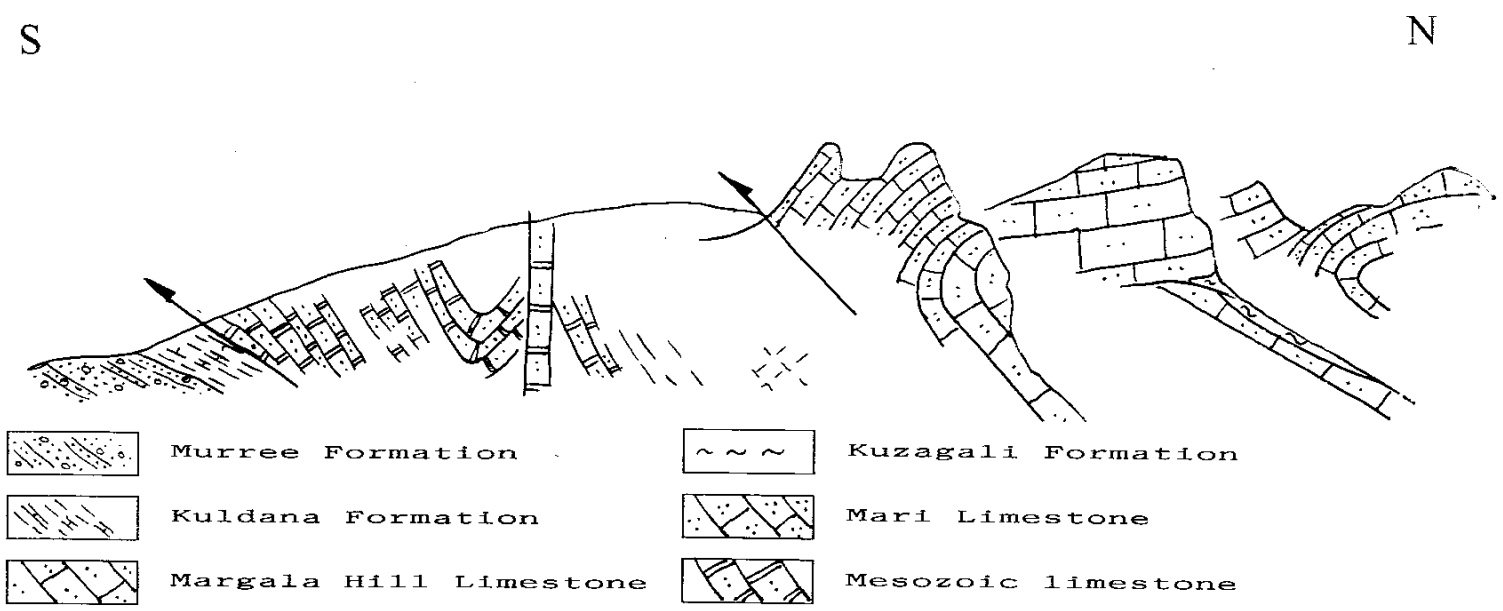


Figure 4- Cross-section of the southern Margala Hills Anticlinorium north of Shah Allahditta (not to scale).

the Margala Hills towards the Nilan valley and further continuing to the east.

These conditions remain unchanged for the sector between Islamabad in the west and Shahdara in the east (Cross-section C-C'). There, Jurassic rocks wedged in between Mari limestone. Since all the valleys could not be visited during this work, future detailed geological mapping might reveal more Jurassic rocks in the Margala Hills Anticlinorium.

The Shahdara-Bashkoli Segment:

East of E 073°10' (about 1 Km northeast of Shahdara) Jurassic rocks have not been encountered. The nature and age of the Tertiary limestone has not always been secured. Generally, 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 E 073°10' (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, (situated 3 Km southwest of Nilan Photu) a wide distribution of Lora Formation can be observed. At Dheri Rakhala, the anticline is composed of Margala Hill limestone. To the south, Lora 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'). No major thrust fault towards the south can be placed there.

However, to the north, a number of folds are added to the Margala Hills Anticlinorium in this segment. North of Dheri Rakhala, widespread folded Lora Formation occurs with occasional synclines filled by Kuldana Formation serving as connecting structures. The Kuldana Formation of the syncline occupied by Nilan valley north of Islamabad continues to the east in this segment in the Kharian valley. East of E 073°10' this syncline occurs near Jhangri (Lat. 33°51' N: Long. 73°14' E). Its continuation is not clear yet in the area of Gambhir and needs further mapping. Between Gado and Kimbi (Cross-section E-E') it is met along the ridge 1000 m north of Kimbi and continues eastward to the north of Gharaga. It might die out further to the east, but again, further field mapping will clarify its further continuation within the Lora Formation of this area.

The Dalhor-Gambhir Anticline

North of the Margala Hills Anticlinorium, a syncline filled by Kuldana Formation sediments is occupying the Nilan valley and the Kharian valley. North of it, a large anticline is present, forming the second ridge of the Margala Hills north of Islamabad. This anticline is named in the present paper Dalhor-Gambhir Anticline.

The southern flank of the Dalhor-Gambhir Anticline has been visited during the fieldwork and its approximate location has been determined in order to arrive at a better understanding of the nature of the Margala Hills mountain front.

In the west at Dalhor, limestone containing isolated quartz grains has been found among a series of yellowish weathering dolomitic limestone and yellow dolomite. 1 km west of Dalhor a lithic quartz sandstone of 50 cm thickness was observed. Because of the similarity of this series of rocks with those observed near Daman-e-Koh, north of Islamabad, the Dalhor rocks have been tentatively assigned a Jurassic age.

These rocks are tectonically overlain by Tertiary limestone containing abundant small Nummulites at places. A precise age cannot be given for the time being. The Tertiary rocks are steeply west dipping.

Southward, the Jurassic rocks are in turn in steep tectonic contact with folded Lora Formation occupying the Nilan valley floor. West of Gokina, outcrps of more resistant limestone force the Nilan river into a southward bend. These limestones have been tentatively assigned to the Margala Hill limestone without any further proof. 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 E 073°08'30" (approximately 1 Km west of Nila Bhotu). At the waterdivide

of Nilan Bhotu steeply dipping (315°/85°) Kuldana Formation is exposed along the road. To the north is Tertiary limestone, dipping northwest (323°/34°). To the south, strongly recumbent folded Lora Formation occurs (Cross-section C-C').

The Dalhor-Gambhir Anticline can be followed to the northeast into the valley of Gambhir. There, the Dalhor-Gambhir Anticline yields into a bundle of folds mainly of Eocene rocks: Lora Formation, Margala Hill limestone with intermittend deeper synclines filled by Kuldana Formation.

South of Lora, Margala Hill limestone seems to be thrust as an anticline over Lora Formation in the valley at Bagnan, thus creating a tectonic window (Cross-section F-F'). However, detailed mapping in the Gambhir-Lora area is necessary to clarify the situation.

At Phalla Gali, the northern front of this fold bundle appears as an overturned anticline of assumed Margala Hill limestone.

North of Phalla Gali, a very steep plunging Anticline of Margala Hill limestone with Kuzagali shale in the core emerges from the Lora Formation west of Lora. This anticline, the northern Phalla Gali Anticline, is clearly overturned to the north. After 3 km, it disappears westwards under Lora Formation. Only a small slice of Margala Hill limestone continues further towards Rupper.

The area northwest of the Lora Synclinorium

The village Lora lies in a synclinal zone, mainly occupied by Lora Formation with deeper synclines of Kuldana Formation. Towards the northwest, they are bound by Jurassic rocks of a foldbelt with at least two Jurassic limestone cores. One is at the bridge west of Rupper across the Katha Rupper and the second one north of Kohala. The fold pattern has not yet been mapped, but field evidences and air-photo interpretation point towards a fold pattern with varying vergences.

At the confluence of Haro Dhund with the Haro Karralan abundant Paleocene Mari limestone and Kuzagali shale are folded in a synclinal position between the just mentioned Jurassic anticline at Kohala in the south, and a further anticline with Jurassic rocks (Spiti and Sikhar) in its core south of Jabri. Jabri Bazar is within a syncline with extremely reduced Lora Formation and Margala Hill limestone at its northern flank, which is in faulted contact to the recumbent folds of Jurassic and Cretaceous limestones of Mount Dubran. The position of the entire syncline with respect to the Mount Dubran of Completely different structural pattern, seems to be the result of a significant fault.

The Mount Dubran fold and thrust structure

The Mt. Dubran and its eastern extension Mount Gita offer a unique view from the north, if compared to the other folds in the area. More or less horizontal layers of an alternation of darker and lighter coloured rocks reveal a fold pattern on closer scrutiny.

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 studied beginning at the bridge north of Jabri, where Jurassic dolomitc limestone is followed by a few meters of black Spiti shale and soft and brown weathering Giumal sandstone. The youngest sediments are Kawagarh limestone (Figure 5). This anticline is comprised a number of south-facing recumbent folds, mostly of Jurassic limestone and dolomite, but also including Giumal sandstone and Spiti shale and possibly Kawagarh limestone.

In the summit region, these folds are thrust by partly overturned Cretaceous limestone and (?)Jurassic dolomite, the Dubran Formation. It is composed of tidal, partly dolomitic limestone that yield into deeper water limestone and dolomitic limestone with abundant sea urchins. 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

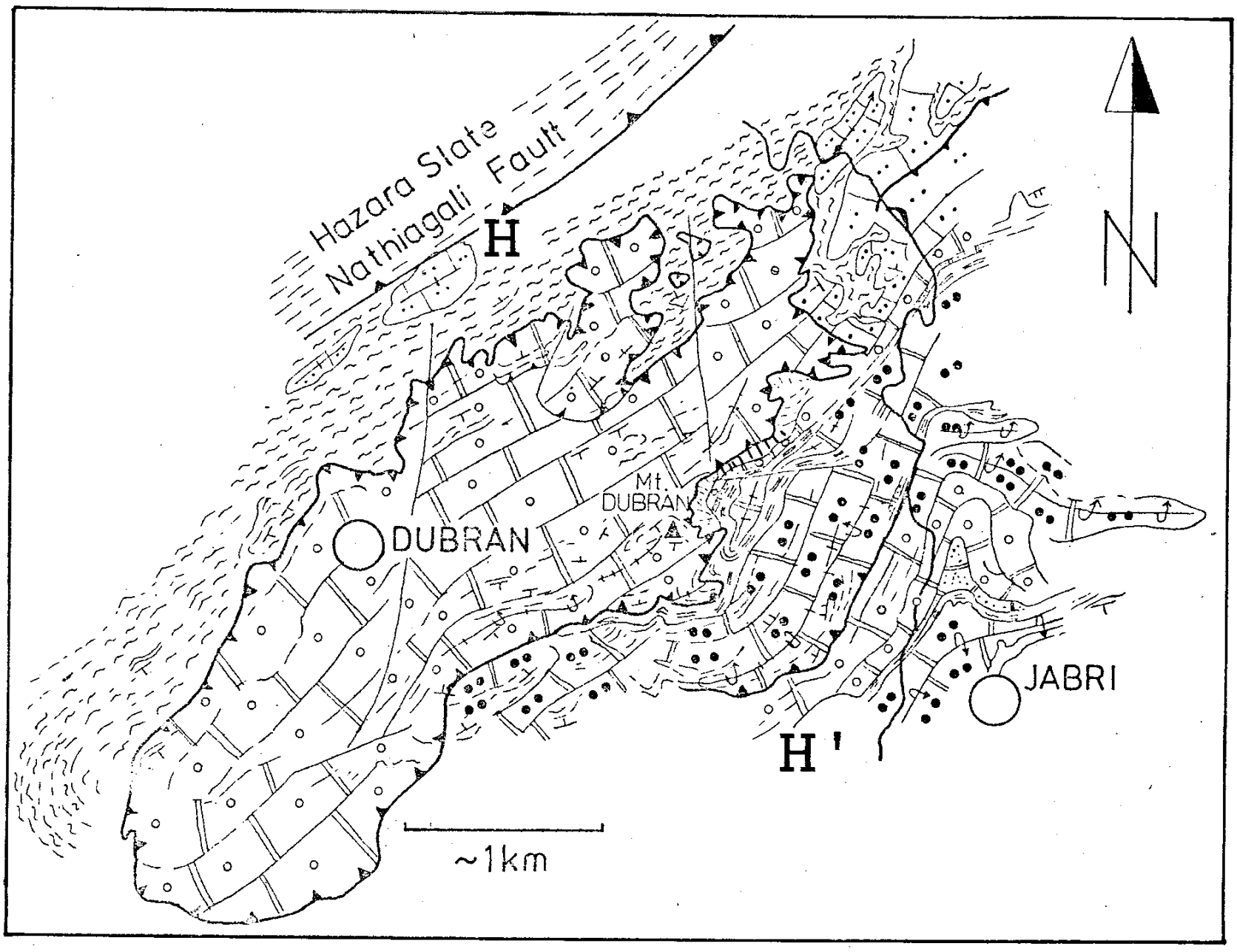
The southern Hazara between the "Murree Fault" in the south and the Nathiagali Fault in the north are a foldbelt built by Mesozoic to Cenozoic Platform sediments of the northwestern Indian Plate. These sediments are strongly folded and dissected by thrusts and faults. At its southern limit, molasse sediments of the Miocene Murree Formation are incorporated in this foldbelt.

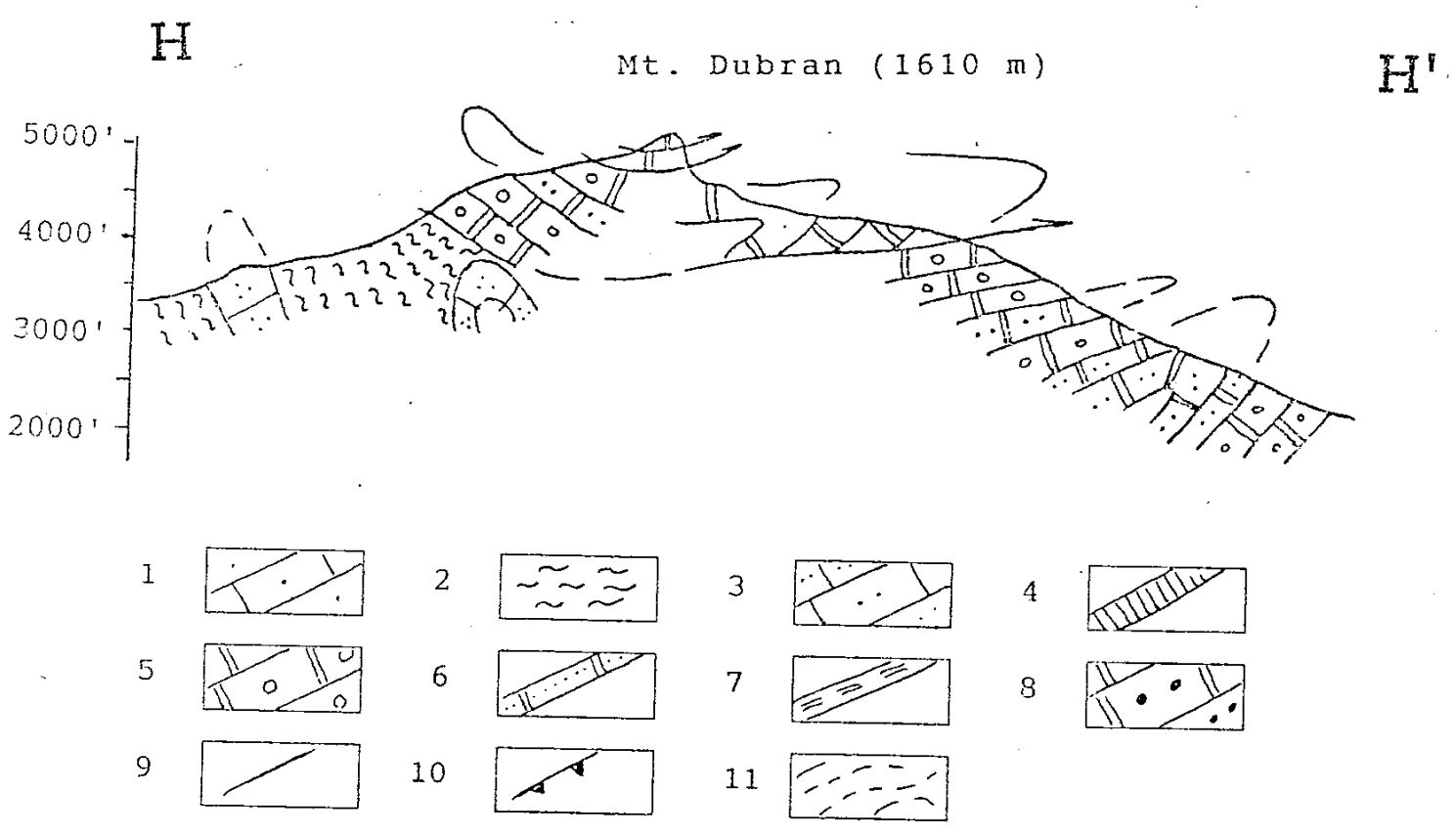
Between Shah Allahditta and Daleh an overturned to the south anticline (Margala Hills Anticlinorium) with Mesozoic rocks in its core is thrust on Kuldana Formation. East of Shahdara, Jurassic rocks have not been observed. There, the anticline axial plain achieves a vertical attitude and the anticline axis starts plunge to the northeast. At Daleh, Lora 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 next anticline to the south i.e. 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.

There is no indication of a major thrust, such as MBT, along the southern margin of the Margala Hills between Shah Allahditta and Murree, 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.

The area under consideration has to be regarded as an parautochtonous structural belt rooted at the northern fringe of the Potwar Plateau. It has been thrust in a piggy-back 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 to be analog to the transform faults bordering the re-entrants of the Western Foldbelt (Bannert et al., 1992 a, 1992 b). The thrusts develop during the process of relative southward propagation of the detached sediments, in response to Eocene





1. Margala Hill limestone
2. Kuzagali shale
3. Mari limestone
4. Hangu Formation
5. Dubran and Kawagarh Lst.
6. Giumal sandstone
7. Spiti shale
8. Sikhar Lst.
9. fault
10. thrust
11. strike of bedrock

Figure 5- Mount Dubran area. Geometrically uncorrected geological sketch of Mt. Dubran (1610 m) from aerial photo interpretation and field observations and geological cross-section.

collision between the Indian Plate and Kohistan Arc at the site of 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.

From our work it can be concluded that at least three detachment horizons occur. One is within or at the base of the Jurassic Sikhar 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.

CONCLUSION

With the help of the interpretation of aerial photographs, limited field investigation, geological mapping and cross-sections we are reaching to the following approach that;

1. Generally, there is consistency in the stratigraphic succession of the area.
2. The area under investigation has been deformed by multivergent folds.
3. No regional thrust fault was observed.
4. Faults are generally reversed in nature and follow the general NE-SW strike.
5. Contrary to the general belief there is no persistent fault between the Mesozoic-Cenozoic sediments and the overlying molasse sediments.
6. These factors show that on regional scale the contact between Mesozoic-Cenozoic and Murree Formation is concordant and the so-called Main Boundary Thrust does not occur at least in the area under investigation.

RECOMMENDATIONS

Present study is a brief summary of the main results of one of our multi-disciplinary research project. A large amount of information is not yet processed and this paper should be considered as a 'working material' for future publications.

This type of investigation should be continued northeastward beyond Ghora Gali until the transform fault west of Muzaffarabad is reached.

More fieldwork is necessary to map the areas of the widespread north vergent folds. The analysis of the fold-pattern, supported by structural analysis of selected microfolds in different strata could lead to a better understanding of the fold-mechanism. Especially in the light of a Pre-Paleocene fold-and-thrust tectonic in the Attock area (Yeats & Hussein, 1987), it is recommended to select the Sikhar limestone and the Lora Formation as the two targets for such a tectonic microfold analysis.

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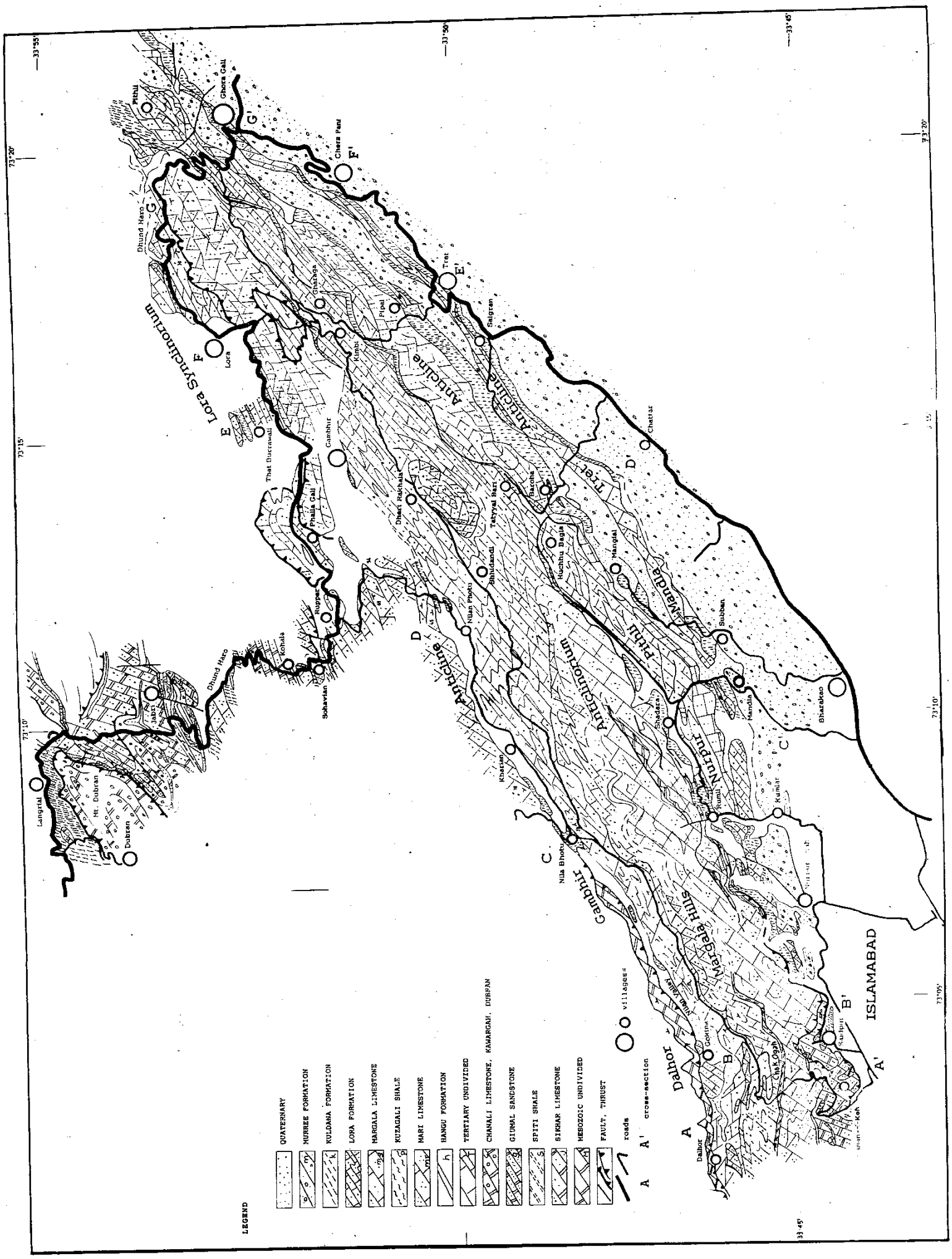
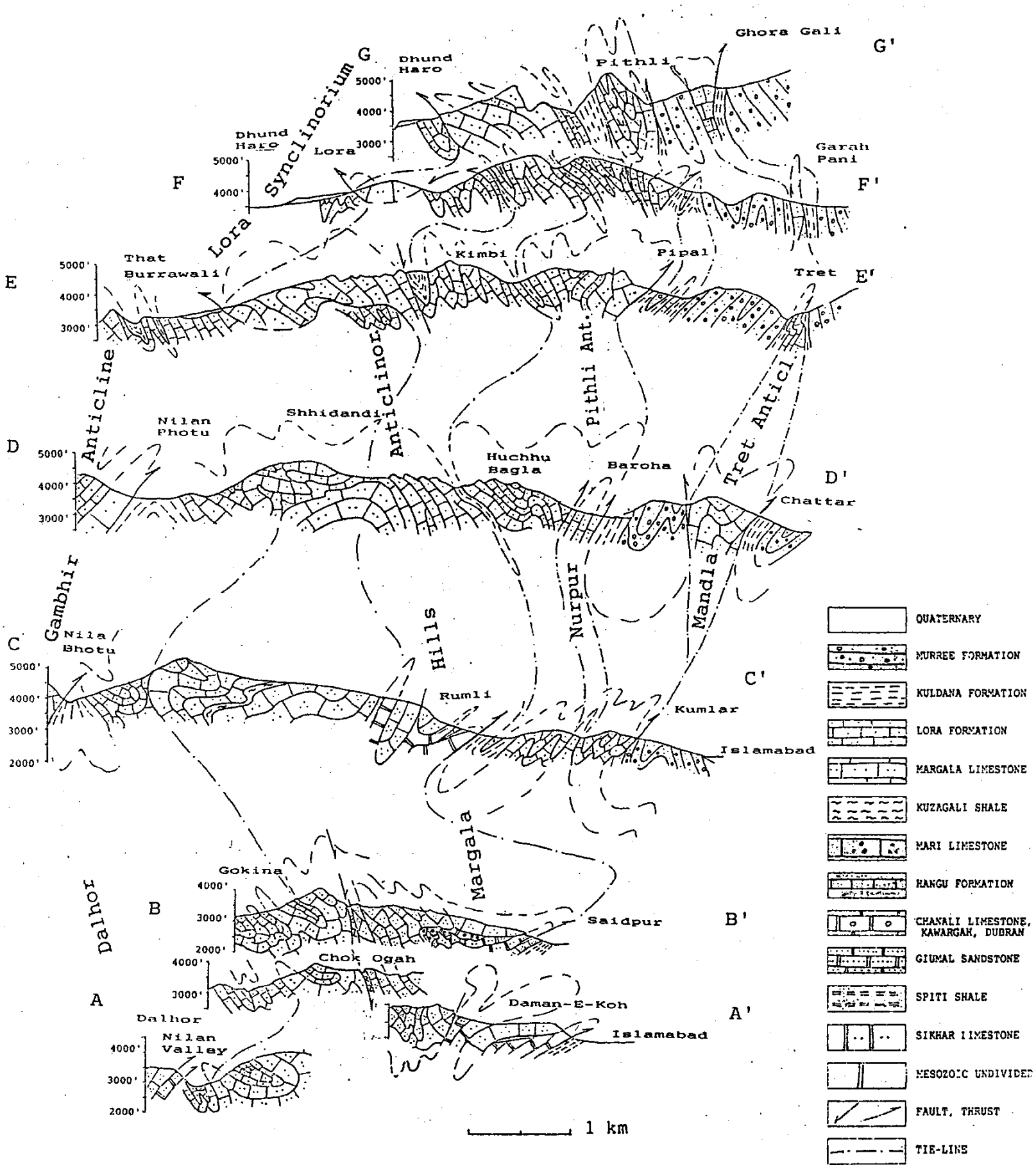


Appendix 1. Geological sketchmap of the Islamabad-Ghora Gali-Langrial area.



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