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A NEW STRUCTURAL MODEL OF THE SOUTHERN SLOPES OF KOHAT PASS, DISTRICT KOHAT, N.W.F.P., PAKISTAN: THE PROBLEM OF NORTH-VERGING FOLDS

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ABSTRACT

The Darra Adam Khel area has been affected by at least three phases of deformation from Cretaceous onwards. The central block was elevated by an early Cenozoic revolution and has since remained a positive area. Miocene rocks were deposited in linear depressions towards north and south of the block. A central problem in this area is north-verging folds that are anomalous to the regional structural pattern.

The chain of repetitions of Samana Suk and Chichali Formations towards the southern part of the area are neither due to tight folding nor repeated fault slicing, as is generally believed. Instead, there are relatively small, open and somewhat overturned folds developed within the souhternmost limb of the main fold, during the last deformational episode, with Chichali Formation being preserved in the synclinal troughs only.

INTRODUCTION

The area under discussion lies beyond the tribal territory of Darra Adam Khel towards Kohat, along the sideways of the Peshawar-Kohat road within longitudes 71° 25′ 00″ & 71° 28′ 30″ E and latitudes 33° 37′ 00″ & 33° 38′ 30″ N, and is covered by Survey of Pakistan toposheet No. 38 O/6.

From Kotal Frontier Constabulary post which is located on top of Kohat pass at the main road, few paths branching towards east and southeast, run through the area. Further south where the main road descends towards plains, a side road turns towards west and runs about 5 miles along the mountain front upto the shrine of Gamkol Sharif (Plate 1).

Besides mapping on 1 : 6,250 scale, structural data was collected from the entire area to understand the tectonic style of the region. The field session started in the fall of 1982 and was concluded by the turn of the year.

The area is multiply deformed and shows a complex map pattern. In order to ascertain the regional structural style of the rock formations, it was considered imperative to map the area on large scale and plot the structural and lithological details as minutely as possible. To determine the intensity of deformation a study of the shape of fossils and oolites was also undertaken.

However, it may be mentioned here that conclusions drawn and the model proposed in this paper are based on the study of a small area. Structural interpretations of the adjoining Darra area are based on limited observations and published informations only. The authors are, however, extending their work and intend to present a more complete picture in future.

Published record of the work within the area is scanty. Khan (1967) established the geological sequence of the formations in the area and mentioned the presence of a syncline near Kotal post. Gardezi *et al.* (1967) published an account of the geology of Darra Adam Khel, with observations of facies changes and their tectonic implications. They mapped about 112 sq km area on 1:50,000 scale, most of which covers the main Darra area. Meissner *et al.* (1968) mapped the entire Kohat quadrangle, mostly with the help of air photos. They have given a good account of the regional structures. Rabbani (1978) has mapped and discussed the geology of Orakzai Agency. His study is mainly paleontological, with a brief note on the economics of the area. Gilmour *et al.* (1981) have concentrated on the carbonate petrography and microfacies of the Samana Suk Formation.

No other record of work about the area under discussion is available except a few unpublished M.Sc. theses of Peshawar University, lying at the Centre's library (for specific titles see references at the end).

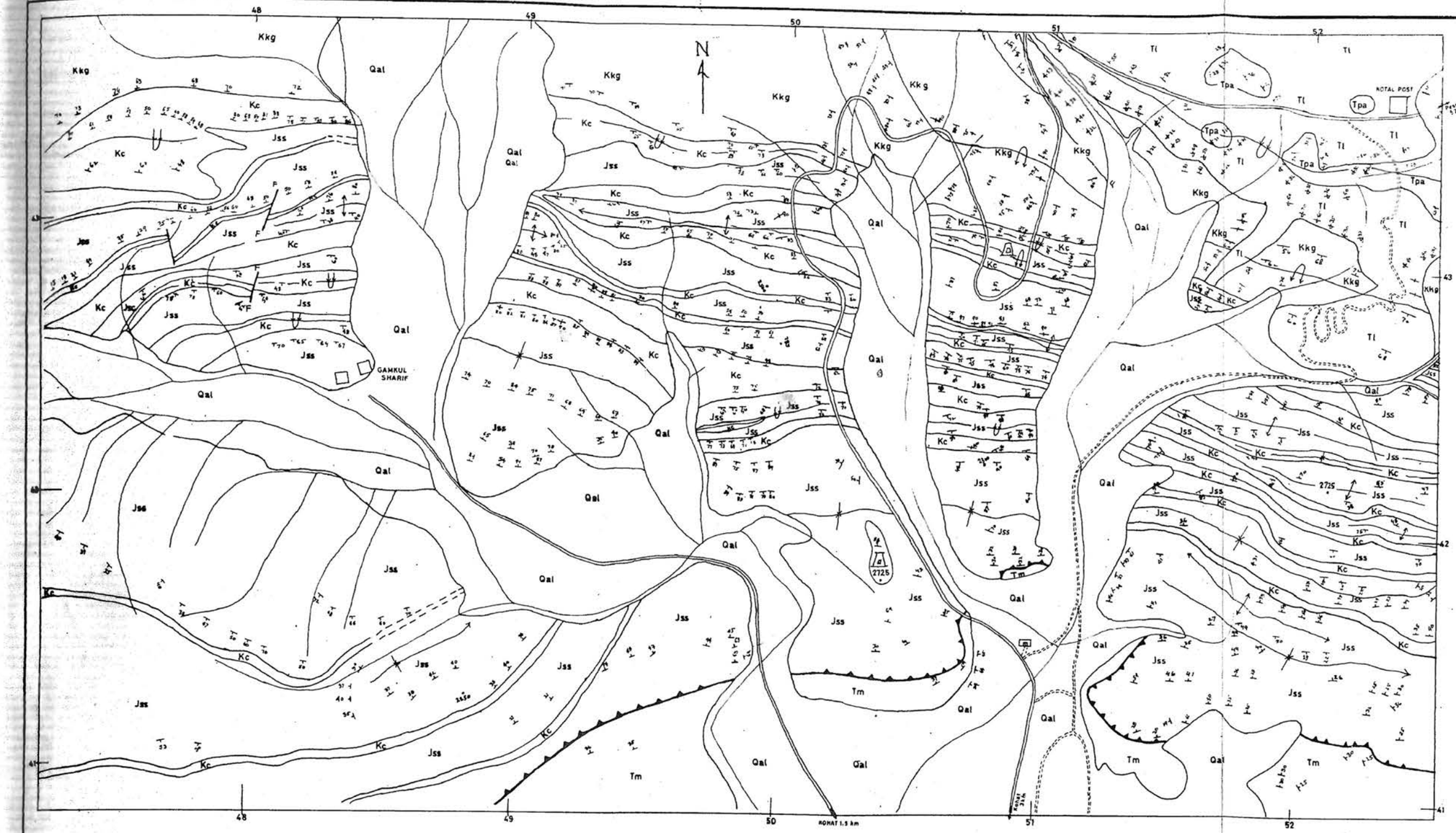
STRATIGRAPHY

Most of the rock formations of the area have diagnostic characters and have been precisely mapped. Lumshiwal Formation of Cretaceous age and the Hangu Formation of early Paleocene time, reported from adjacent Darra area are, however, not established in this part. Table 1 shows the stratigraphic sequence of the area.

The writers of the present paper do not believe that the coarse-grained inclusions within Patala Formation represent facies change (Gardezi *et al.*, 1976). This unit is exclusive of the upper part of the Patala Formation and exists as lensoid bodies. These gritty bands and lenses probably represent channel fills within Patala Formation.

STRUCTURAL FEATURES OF THE AREA

The area has undergone several deformational events. Intricate outcrop patterns have developed due to interferring folds of different generations. The main mode of deformation was buckle folding and no superposed element of homogeneous deformation is present.



EXPLANATIONS

Qal
Alluvium

Tm
Murree Formation
Sandstone, purple, dark-grayish-brown & greenish-gray, conglomeratic and shale, purple and reddish-brown

Tpa
Patala Formation
Sandstone, greenish-gray, coarse-grained, cross-bedded, massive, conglomeratic, shale, dark-gray, hard, splintery, changes eastward into interbedded shale and nodular limestone

Tl
Lockhart Formation
Limestone, dark-gray to black, massive nodular, fetid odor; formaminifera common

Kkg
Kawagarh Formation
Limestone, medium to thick bedded, light to medium gray, finely crystalline to aphanitic, with concholdal fracture

Kc
Chichali Formation
Shale, greenish-gray, greenish-brown, at places blackish-green Base is marked by sandy dolomitic beds. Shale is sandy, soft, glauconitic and fossiliferous containing Belemnites and Ammonites

Jss
Samana Suk Formation
Limestone, light-gray, oolitic, fossiliferous, cherty and dolomitic at places

Contacts — Faults F—F — Thrust fault — 50 Inclined.
Vertical — Overturned — 2866 Peaks — Khass. Post
Houses — Metalled Road — Unmetalled Road

INDEX TO SHEETS

38 0/1	38 0/5	38 0/9
38 0/2	38 0/6	38 0/10
38 0/3	38 0/7	38 0/11

Hinge traces of:
Anticline
Overturned
Syncline
Overturned
Plunge direction

0 250 500 metres
Scale

GEOLOGICAL MAP OF SOUTHERN SLOPE OF DARA ADAM KHEL, DISTRICT KOHAT. N.W.F.P PAKISTAN.

TABLE 1. STRATIGRAPHIC SEQUENCE IN THE DARRA ADAM KHEL AREA.

Name	Age	Thickness	Lithology
Murree Formation	Early Miocene	20 m	Clay, sandstone, siltsone and conglomerate.
Patala Formation	Late Paleocene	90 m	Shale, limestone and sandstone.
Lockhart Formation	Paleocene	200 m	Limestone: nodular, bituminous.
	——DISCONFORMITY——		
Kawagarh Formation	Late Cretaceous	100 m	Limestone: sublithographic to lithographic.
	——DISCONFORMITY——		
Chichali Formation	Early Cretaceous	10 m	Galuconitic sandstone, shale, dolomitic limestone.
	——DISCONFORMITY——		
Samana Suk Formation	Middle Jurassic	150 m	Limestone: oolitic, dolomitic and cherty.
	Base not exposed.		

Structurally the area can be divided into three distinct structural domains due to great contrast in the pattern of deformation. These domains are also differentiated on the basis of rocks of different age groups and mechanical response. The area dominated by the oldest rocks is more deformed and has experienced at least three generations of folding. The domain which exposes the rocks of intermediate age shows comparatively lesser impact of forces, while the youngest rocks are only mildly deformed.

Following is a brief description of structural domains :

Domain I : (Northern and northeastern part where the Kawagarh, Lockhart and Patala Formations of late Cretaceous and Paleocene age are exposed).

The broad structural feature of this domain is an overturned fold. The three formations of the area form a syncline where Patala Formation is lying in the core. From Kotal post for some distance southwards one crosses the partly eroded limb of the syncline (Plate 1; Fig. 1a). The exposure of Patala and Lockhart Formations, within tribal territory of Darra area, just before Kotal post, mark the other limb of the syncline (Fig. 1b).

The dips of Patala Formation near Kotal post are very gentle (averaging 32° S). Moving south, the dips gradually increase till Lockhart Formation appears overlying Patala Formation. The sequence here is overturned. Bedding in Lockhart Formation turns suddenly from sub-horizontal to very steep. This is the ver-

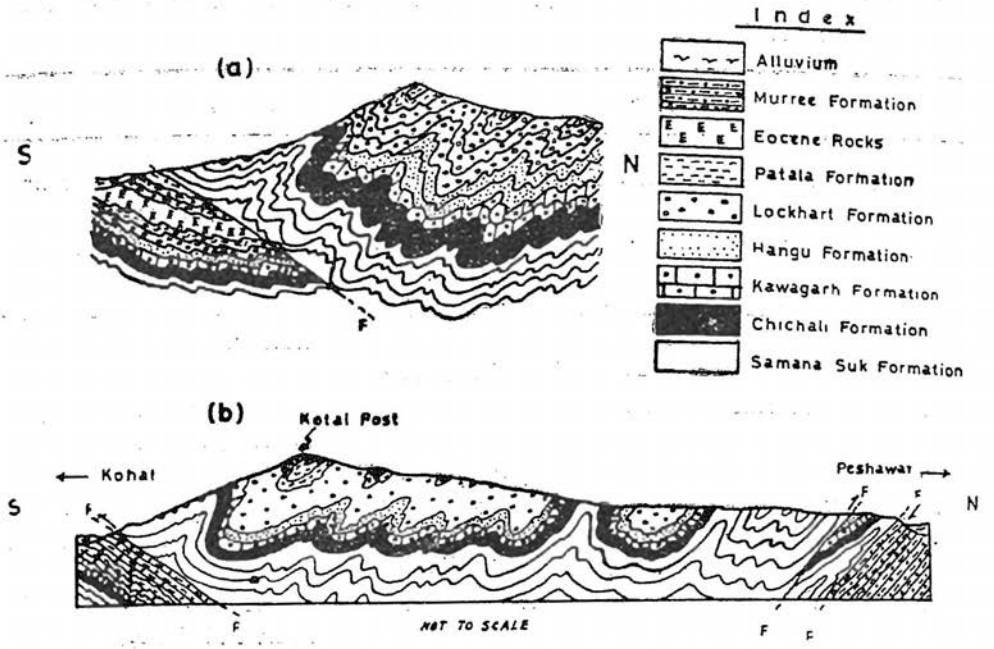


Fig. 1 a. Schematic section illustrating proposed structural model of southern slopes of the Kohat Pass.

b. Panoramic section of Darra Adam Khel area between Peshawar and Kohat (Geological information north of Kotal post are borrowed from Gardezi *et al.*, 1976 and Meissner *et al.*, 1968).

tical segment of the overturned syncline. Further south the well-bedded lime stone and dolomite of Kawagarh Formation start dipping very steeply toward north (here the normal limb of syncline starts appearing).

The gently dipping segment, the sharp bend and the vertical wall of the nodular limestone from Lockhart Formation turning inside to dip towards north and all other features discussed above can be seen on foot tracks that start from Kotal post and descend towards southeast, and then turn south into Kohat plain. These structures extend across the road to the west.

Domain II : (Southeastern, central and northwestern part where Chichali and Samana Suk Formations are exposed).

Beyond Kawagarh Formation what is seen on the surface is the southern limb of the adjacent southern anticline. Here the chain of repititions of Chichali and Samana Suk Formations start. At least 9 exposures of Samana Suk Formation with intervening bands of Chichali Formation, some of which are discontinuous, have been mapped within a horizontal distance of 2 km as measured across the strike of the formation (Plate 1). The two formations strike ESE–WNW but are variously dipping north or south. Out of a total of 380 dip measurements from the entire domain, 161 range from 45° to 65°, only 74 measurements are of very steep dip i.e. 75° or more. This is a situation entirely different from domain 1.

The thickness of the Samana Suk Formation is reported by Fatmi (1968) to range from 186m to 366m, while Chichali Formation varies from 12m to 27m. The Chichali Formation measured in this domain varies from 1.5m to 4.0m only. Even the thickest Samana Suk exposure does not reach 30m, except in the gently dipping part towards its contact with the Murrees (Plate 1). This indicates that nowhere is the entire thickness of the two formations exposed.

Anoher noteworthy feature of the two formations relates to their degree of deformation. The formations are highly fossiliferous. In addition, the Samana Suk Formation is entirely oolitic at various levels, especially its central part. Thin section studies carried out to ascertain the extent of deformation, recorded specially in oolitic rocks, indicate that they are little deformed (Fig. 2). Gilmour *et al.*

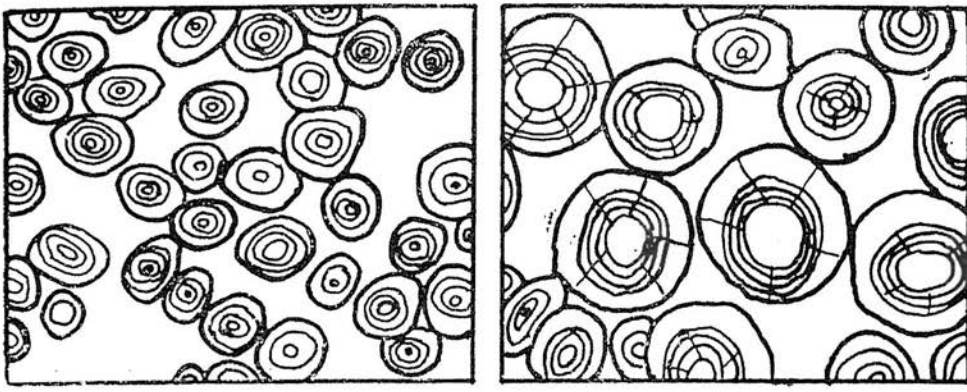


Fig. 2 Camera lucida sketches showing outline of oolites from Samana Suk Formation (random samples from two different localities).

(1981) report a great variety of megafossils, microfossils and oolites from the area. They state that "rounded foraminifera, algal plates and peloids occur with ooids". The plates in their paper, especially I-3, II and I-6, very clearly show ooids and microfossils. This feature indicates that the element of homogeneous deformation, imprinted on heterogeneous deformation (fold producing deformation), is negligible and confirms that the Samana Suk Formation is not tectonically thinned.

The most important problem, particularly in this domain, is the reverse vergence of folds. Moving towards the thrust the folds gradually show strong vergence towards north. This is an anomalous situation keeping in view the regional structural pattern of the area.

Immediately close to Murree Thrust, the upper limb of the main fold lies in sub-horizontal position with a series of minor folds developed within it (Fig. 1a).

Domain III : (South and southwestern part, where Murree Formation is exposed).

This structural domain separates itself from domain II by a major discontinuity, i.e. a thrust which dips gently towards north. The formation is dominantly composed of shales and clays with a few coarse units. It is a comparatively incompetent formation and, in this area, shows no structures except tilted regular bedding in sandy units.

The massive and competent Samana Suk Formation was pushed over the shaly and clayey incompetent Murrees with the result that little activity characteristic of thrusting is seen here. The Murrees, instead of offering resistance in being overridden, might have facilitated the uphill movement of Samana Suk Formation. The latter, in turn, did not develop tight folds or imbricate fault slices. The dips of Murree Formation, the thrust plane and the Samana Suk Formation, in this vicinity of the region, are quite gentle (average 36° N).

CONCLUSIONS

From the above discussion the following conclusions can be drawn:

(i) The broad structural features of the area are :

(a) Northern overturned syncline with late Paleocene rocks in the core;

(b) Southern anticline exposing Jurassic and Cretaceous rocks on its southern limb; and

(c) Low angle fault (Murree Thrust), along which Jurassic rocks are thrust over Miocene rocks.

(ii) From Kotal post towards south, the sequence of rocks is upside down for some distance till the start of the anticline.

(iii) The area has been affected by several episodes of north-south compression and as a result has developed structures of different generations.

(iv) Some geologists consider that the frequent alternations of Samana Suk and Chichali Formations in the area may be due to either of the following conditions (personal communications with local and foreign geologists during traverses along the Kohat road):

a– Tight, steeply inclined or isoclinal folds;

b– Repeated fault slices related to the thrust.

The field evidence is against the occurrence of steeply inclined tight folds in this area. The structures show that large scale shortening, which generally accompanies tight folding, did not occur (indicated by shapes of oolites and fossils). Besides, the thickness of the two formations exposed on the surface in case of subvertical isoclinal folds, should have been much more than that observed. The identification of open folds in the area also does not favour this idea.

Neither repeated fault slices nor imbricate fault structures are confirmed by actual observation in the field. The beds dip north and south within short distances without tectonic disruption.

(v) One of the most significant features north of the Murree Thrust is the reverse vergence of the folds. This can be explained by assuming that the thrust gradually becomes gentle at depth. The folds during their movement up along the thrust-plane rotated in the present position (Fig. 3).

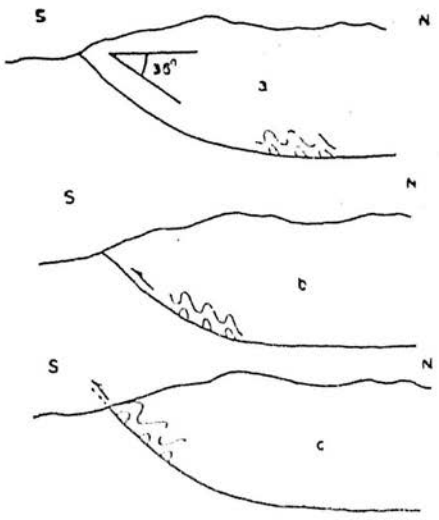


Fig. 3 a—c. Different stages, showing possible vergence reversal on Murree Thrust.

(vi) The present work shows that open, asymmetric and somewhat overturned local folds dominate the southern part of the area where repetitions of Samana Suk and Chichali Formations are found. Exceptionally small exposure of the two formations, their repeated alternations and the open folding of the area suggest that these are young folds, superimposed on the rising limb of the southern anticline at the time of thrusting. Chichali Formation now appears only in the synclinal trough (Fig. 1a).

(vii) The recumbent folds present within the limb of the main anticline are second order folds which, after rotation of the main fold, have acquired their present position.

Proposed Structural Model of the Region.

After the Jurassic and Cretaceous rocks were deposited, the area was first deformed producing broad folds on which the Paleocene-Eocene rock sequence was laid unconformably. The episode of deformation that followed, produced major overturned folds and elevated the central part of the area to the level that it remained a positive land from then onwards. Murree sediments of Miocene time were deposited on either side of this central "Massif".

The major deformational episode followed Miocene when Murrees on the northern flank underthust the front block. The structural patterns already set

within the rocks became more pronounced. The folds got highly overturned and new generations were imprinted giving rise to complex patterns.

Towards southern end of the block the upthrust movement of major folds reversed the vergence and rotated the southern limb of the anticline to sub-horizontal position. As Murrees were incompetent rocks, they did not offer much resistance in being overridden. However, the sub-horizontal limb of the fold, in the course of thrusting, developed repeated plications which, with few exceptions, are open folds. The thin and repeated Chichali Formation exposures mark the synclinal trough of these folds.

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