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STRUCTURES IN THE HANGINGWALL OF THE MAIN BOUNDARY THRUST: POST- FOLDING THRUST AND NORMAL FAULTS FROM THE KOTAL-PASS AREA, KOHAT RANGE, N. PAKISTAN

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ABSTRACT

The Main Boundary Thrust is a wide, complexly folded and faulted zone which uplifted the Kohat range, and tectonically emplaced the Mesozoic-Cenozoic shelf carbonate succession over the Tertiary molasse sediments. The MBT zone is characterized main ly by major thrust faults both imbricate and duplex type and tight folds. Tight folding along the MBT zone resulted in the formation of out-of-the syncline faulting. Late stage (post folding and thrust faulting) development of normal faults at the base of the Paleocene succession further deformed the MBT zone in the Kohat area. The Paleocene strata in the hanging wall of southward propagating normal faults is subhorizontal to shallowly dipping northward, and lies discordantly over the Mesozoic succession. The normal faults are of localized nature in the MBT zone and are reported for the first time from the Kohat range. The normal faults may have exploited the weaker horizons generated during earlier thrusting such as out-of-the syncline faults. Presence of thick fault breccia along the fault plane suggests that these structures may have formed close to near surface conditions during uplift of the Kohat range.

INTRODUCTION

The Main Boundary Thrust (MBT) is a regional lineament in the external zone of the Himalayan thrust-fold belt in N. Pakistan, which brings the Mesozoic-Cenozoic shelf sediments of the Margala-Kalachitta-Kohat Hill ranges to lie tectonically over a pile of molasse sediments deposited in the foreland basin. Disruption along the MBT zone started probably around early Miocene times as suggested by the involvement of the late Oligocene-early Miocene Murree Formation in deformation (Burbank, 1983). A diverse assemblage of structures is reported associated with this major fault structure,

including thrust faults in imbricate and duplex systems, backthrusts and divergent fold structures. These structures are spread over an approximately 20 km wide zone in the Kohat range, where they form a major pop-up structure (Ghauri et al., in prep.).

Earlier accounts of the MBT and its associated structures are given by Cotter (1933). Various segments of the MBT zone have been subsequently mapped in relatively greater details, resulting in the recognition of a large number of fold and thrust structures associated with it (Gardezi, 1974; Gardezi et al., 1976; Ghauri et al., 1983; Akhtar et al., 1984; Izatt, 1990).

Recently, we have started a programme of reinvestigation of the structures in the hangingwall of the MBT, concentrating in the part of the Kohat range in the Dara Adam Khel area (K.A. Turi, work in progress). In the process we have carried out detailed analyses of the thrust and fold structures which were previously outlined by Gardezi et al. (1976) and Ghauri et al. (1983). A detailed account of them will be published subsequently. In this paper we present data on a set of out-of-the syncline thrust and normal fault structures from the Kotal-Pass area of the Kohat range (Fig. 1), which have not been previously recognized, and which, in our opinion, represent the youngest phase of the tectonic activity associated with the MBT.

GENERAL STRUCTURAL SETUP

The Kohat range is characterized by a complex set of structures. The MBT together with a major backthrust, delimits the range at its southern and northern flanks, separating it, respectively, from the plains of Kohat and Peshawar (Fig. 1). These structures divergently thrust the Samana Suk Formation of Jurassic age over the Oligocene-Miocene Murree Formations, on the either side of the range. Within the range, there is an interesting structural disposition of the stratigraphy. The Mesozoic strata including Samana Suk, Chichali, Lumshiwall and Kawagarh Formations, are mainly exposed along the northern and southern flanks of the range (in the immediate hangingwalls of the two faults mentioned above), whereas the Paleocene Lockhart and Patala Formations occupy the central part. In the latter, there is a repetition of the Lockhart and Patala Formations due to both tight, cylindrical folding, and imbrication above a detachment occurring at the base of the Lockhart Formation. The repetition in the older set of rock formations in the either flanks of the range (for instance that of the Samana Suk and the Chichali Formations) is probably due to imbrication below a roof thrust which was apparently located in the Chichali-Lumshiwall Formations. A later strong phase of folding has developed complex interference patterns, which have further contributed to the uplift of the range. The structures described in this paper postdate all these structures, and include 1) out-of-the-syncline thrust faults, which record the culmination of shortening and uplift in the Kohat range, and 2) a set of

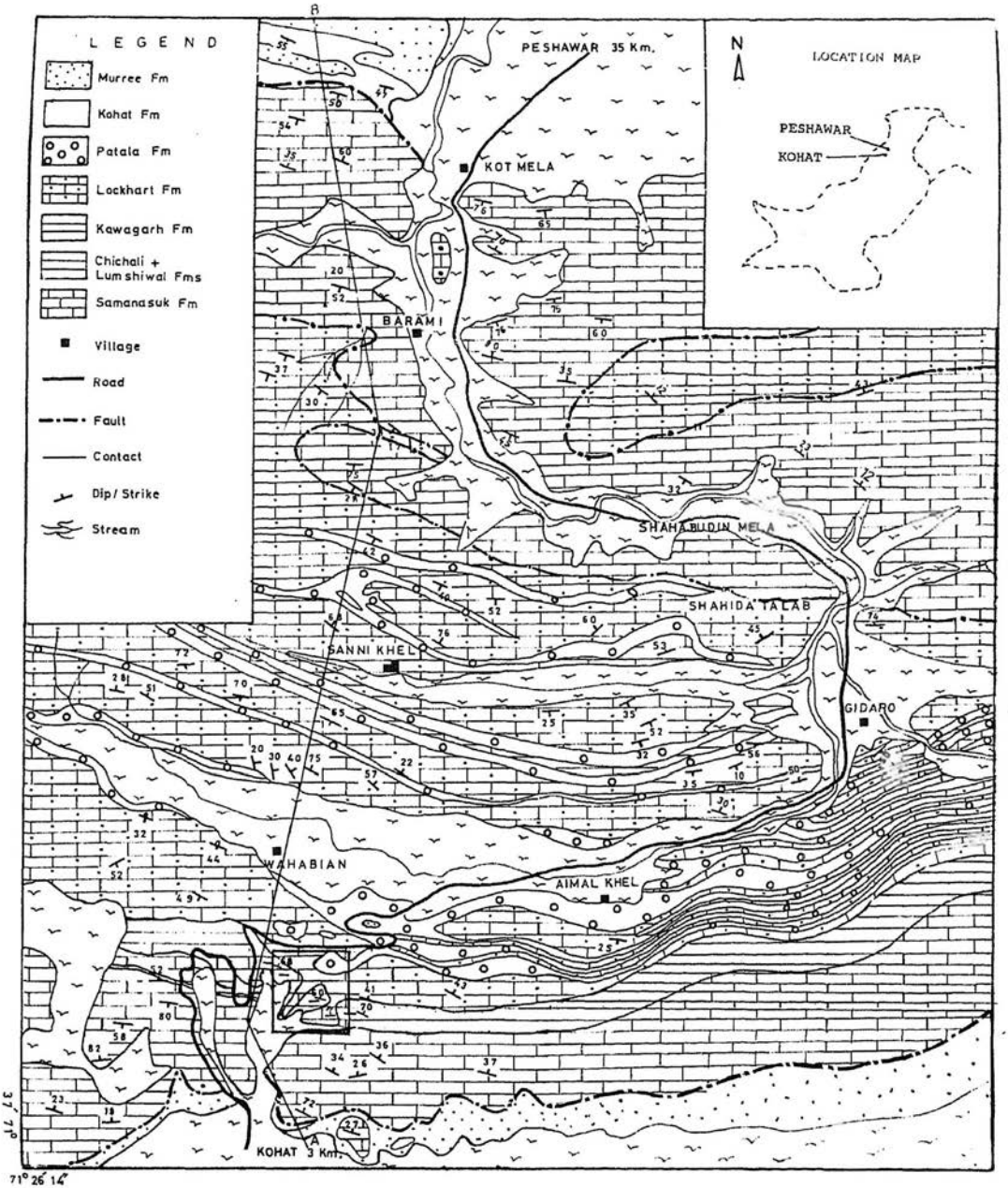

Fig. 1. Geological map of the Dara Adamkhel-Kotal transect, Kohat Hill range (After Gardezi et al., 1976; Ghauri et al., 1983).

normal faults, which mark the gravitational adjustments following abnormal uplift associated with the MBT and its associated structures.

LATE, POST-FOLDING FAULT STRUCTURES

The major structure in the Kotal Pass area of the Kohat Range is a broad, box-shaped syncline, which has both of its southeastern and southwestern limbs tightly overturned (Fig. 2). This large fold structure involves entire stratigraphy exposed in the Kohat range from the Samana Suk Formation of Jurassic age to the Paleocene Patala Formation. A traverse along a foot track on the eastern side of th : valley leading to the Kohat plain from the Kotal Pass, gives an excellent view of the sou heastern overturned limb of this syncline (Fig. 2). Just to the southeast of the Kotal Check post, there are southward-dipping beds of the Patala Formation exposed in the overturned limb of the syncline, which are successively overlain by older formations to the s. ath. Generally there is a close correspondence in the attitude of the various rock units involved in this overturned limb, but there is a strong discrepancy found at the contact between the Lockhart and the Kawagarh Formations. Although, apparently there is no tectonic missing of the stratigraphy at this contact, the attitude of the bedding in the two formations is clearly out of correspondence (Fig. 3), suggesting presence of a fault structure at this contact. A follow up in the ridges to the west (Fig. 2) shows that the contact between the Lockhart and Kawagarh Formations is faulted for almost its entire length of exposure. The beds in the Lockhart and overlying Patala Formations are either horizontal or only shallowly dipping to the north, but they dip steeply ($\sim 70^{\circ}$) towards north in the underlying Kawagarh Formation (Fig. 3). We consider this fault to be a south-verging out-of-the-syncline thrust, which brings near-horizontal strata of the Lockhart Formation from the core of the syncline displaced on top of the steep beds of the Kawagarh formation in the southeastern limb.

A further evidence of south-verging thrust faulting is met in the imbrication of the Paleocence sequence on the ridge to the south of the Kotal Pass. Here a tectonic slice of the Lockhart Formation occurs on top of a thin strata of Paleocene, which is a part of a normal Lockhart-Patala succession (Fig. 4). This fault which brings the Lockhart Formation on top of the Patala Formation has the southward sense of vergence and tectonic position in the southern limb of the Kotal syncline which is almost identical to the fault described above.

An indirect consequence of the south-verging, out-of-the-syncline thrusting in the southern limb of the Kotal syncline has been an allocthonous displacement of near-horizontal Paleocene strata on top of near-vertical Mesozoic succession. Ghauri et al. (1983) mapped, just to the south of the Kotal Pass, two lobe-shapped, southward directed projections of the Paleocene Lockhart and Patala Formations discordantly overlying the rest of the stratigraphy in this part of the Kohat Range (Fig. 2, 5). There is a marked difference in the attitude of bedding in these tectonic lobate projections of the Paleocene strata and the underlying Mesozoic succession. In the former, the bedding is either horizontal or dips only shallowly towards north (rarely exceeding 35°), while in the underlying Mesozoic succession, the dips are rarely less steeper than 60°.

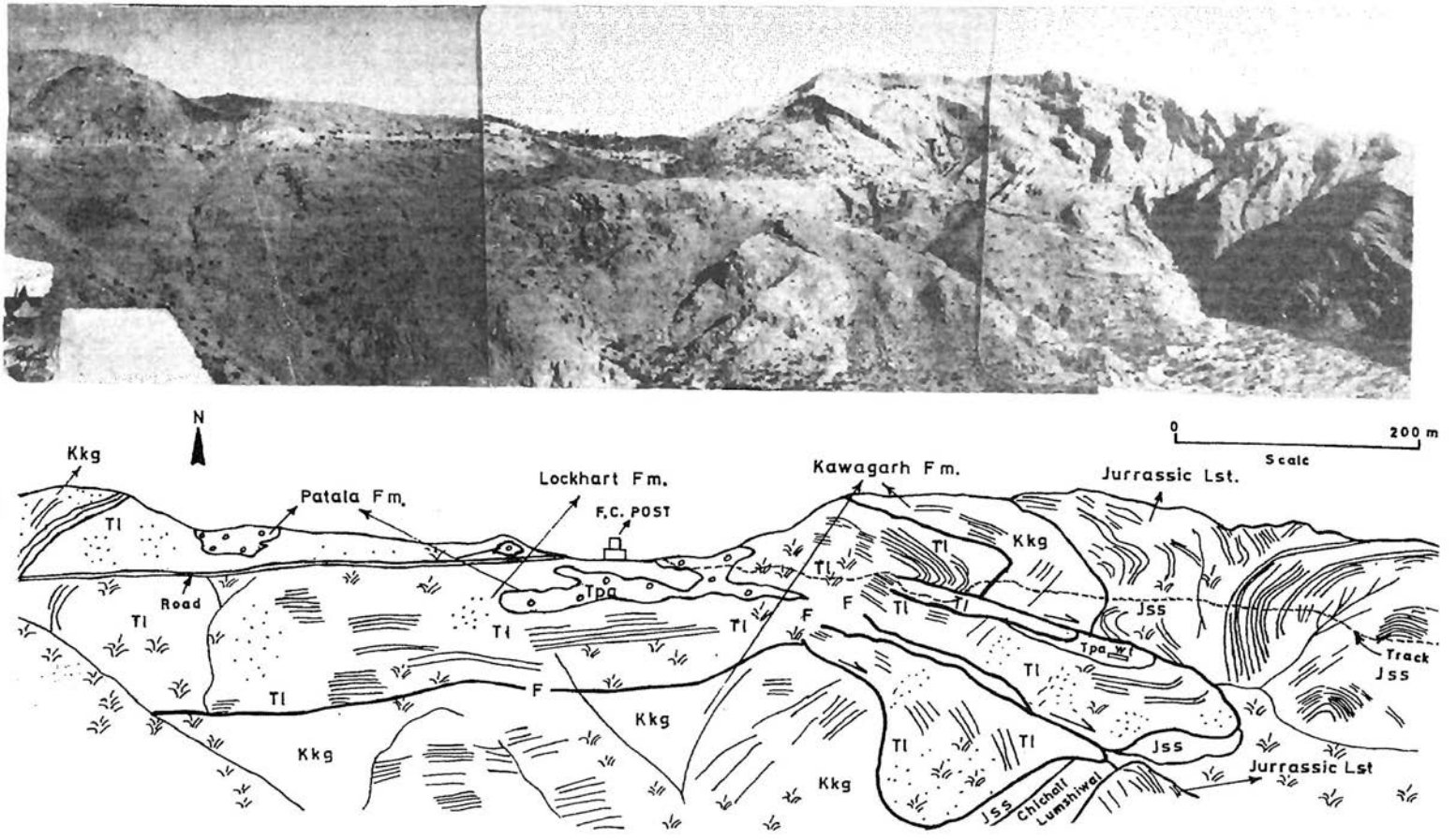

Fig. 2. A panoramic view of the Kotal Pass area, Kohat range, looking from south. Note the major box-shaped syncline, with its northeastern overturned limbs. Two allocthonous blocks comprising Paleocene Lockhart and Patala Formations, tectonically overly the near-vertical Mesozoic succession (right lower parts of the photograph).

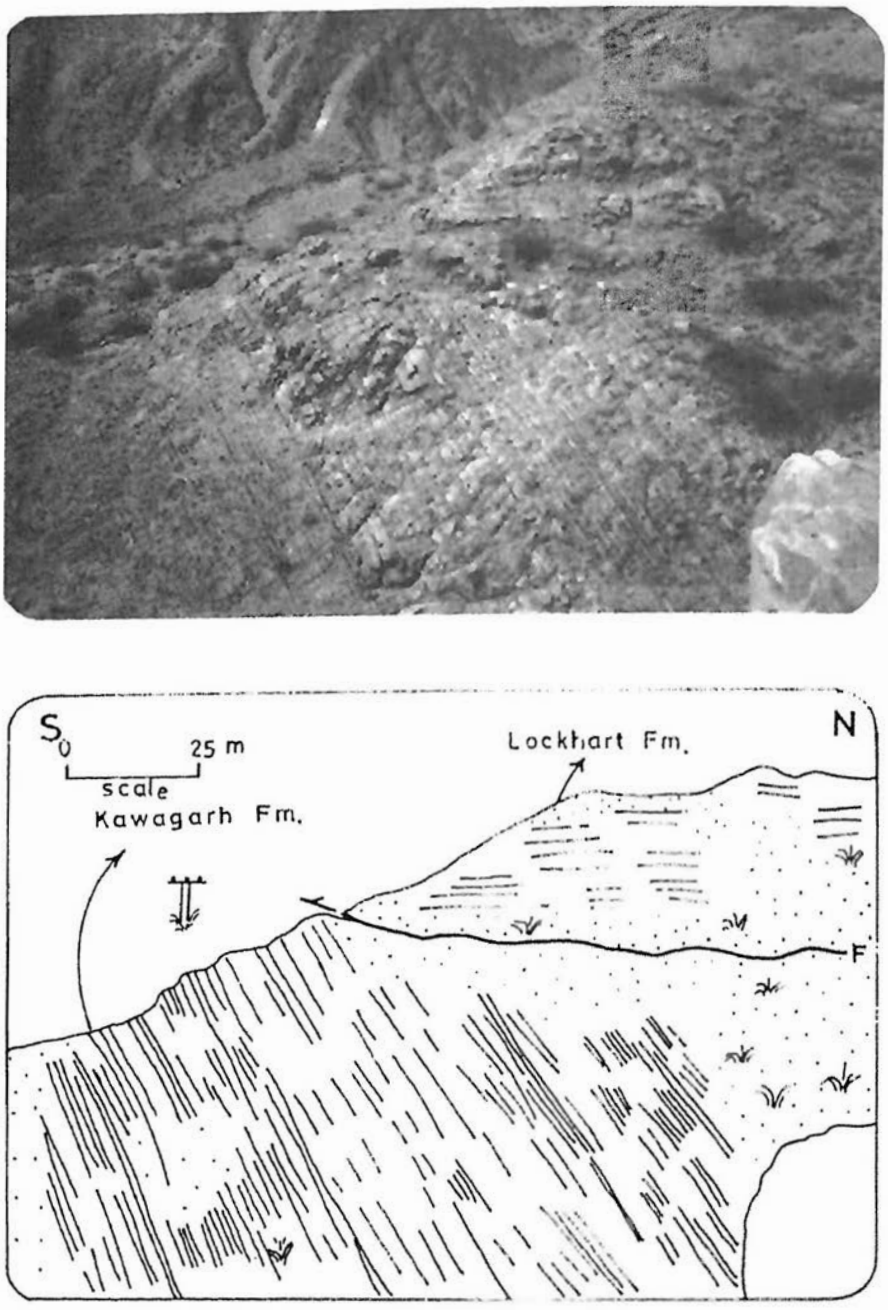

Fig. 3. A shallowly south dipping strata of the Lockhart Formation resting tectonically on steep beds of the Kawagarh Formation.

This type of relationship, in our opinion, is nowhere near to the normal stratigraphic type as shown by Ghauri et al. (1983).

The tectonic relationship of the fault-bounded, allocthonous blocks of the Paleocene strata on top of the Mesozoic succession is illustrated in Figs. 4, 5 & 6. Commonly they are located over a shallowly south- dipping fault plane at the base of the Paleocene succession. The strata in the hangingwall of these faults is either horizontal or dips shallowly towards north, suggesting that the basal fault cuts downward in the stratigraphy as it propagated southward. There appears to be little effect of this fault structure on the attitude of the underlying Mesozoic succession, which is vertical to highly steep, and is remarkably continuous in its E-W strike.

An aspect which is probably worth mentioning here is the existence of "window" type structures in between and on the either side of the southward projections of the tectonic blocks of the Paleocene strata. Apparently these "windows" are a result of topographic effect, as they coincide and are roughly parallel to the N-S running valleys on the sides of the two ridges which are occupied by the tectonic blocks of the Paleocene strata. There is a considerable difference in the altitude of the two tectonic blocks, the eastern one lies almost near to the valley floor, while the western one being approximately 200-300 m high near to the top of the ridge. Since the two tectonic blocks occupying the adjacent ridges are similar in all respects, e.g., stratigraphy, attitude of their basal fault planes, and that of the bedding planes within these blocks, it is probable that originally the two blocks were continuous and were displaced along a single fault. The difference in the altitude of the fault planes at the bases of the two tectonic blocks may be due to an originally curvilinear nature of the basal fault plane, with an eastward tilt which resulted in the much lower position of the eastern block relative to that of the western.

DISCUSSION

Whereas the recognition of faults in the Kotal Pass area has been a relatively simple matter of observation, owing mainly to dramatically good exposures and well established stratigraphy (Gardezi et al., 1976; Ghauri et al., 1983), the assessment about their nature is not that straightforward. The shallowly north-dipping fault (Fig. 3) at the contact between the Lockhart and the Kawagarh Formations was apparently reverse in its sense of movement, as it brought near-horizontal strata of the Lockhart Formation probably from the core of the box-shaped syncline to lie on top of the steeply northward dipping strata of the Kawagarh Formation in the southeastern limb of the syncline. This fault owes its initiation probably to tight folding in area which resulted in south-verging out-of-the-syncline thrusting. Late stage movement along this fault transported the Paleocene strata southward to lie upon Mesozoic succession as tectonic

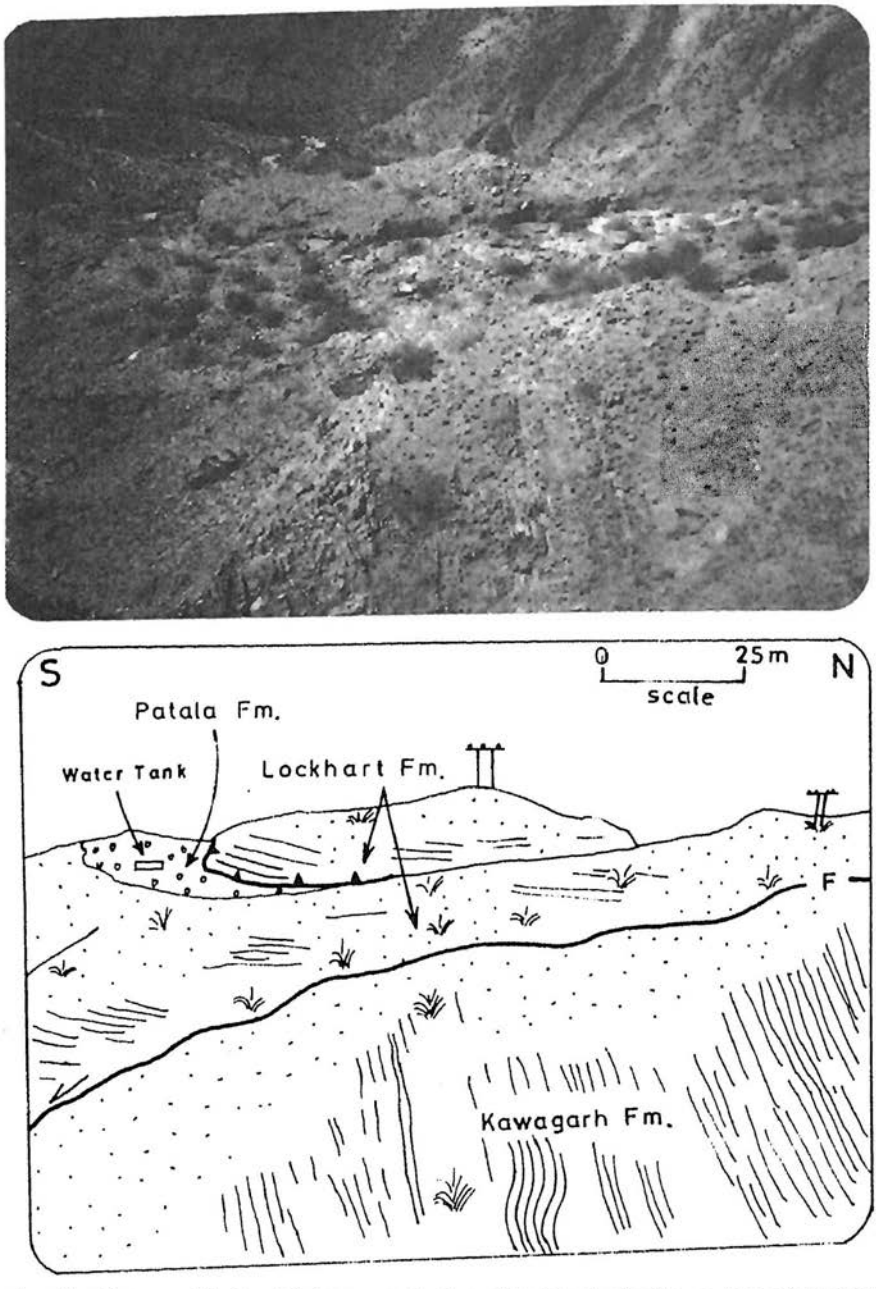

Fig. 4. An allocthonous block of Palcocene strata resting tectonically on top of steeply dipping Mesozoic succession along a normal fault. Within the tectonic block there is an imbricate thrust which brings the Lockhart Formation t › lie on top of a normal Lockhart - Patala succession.

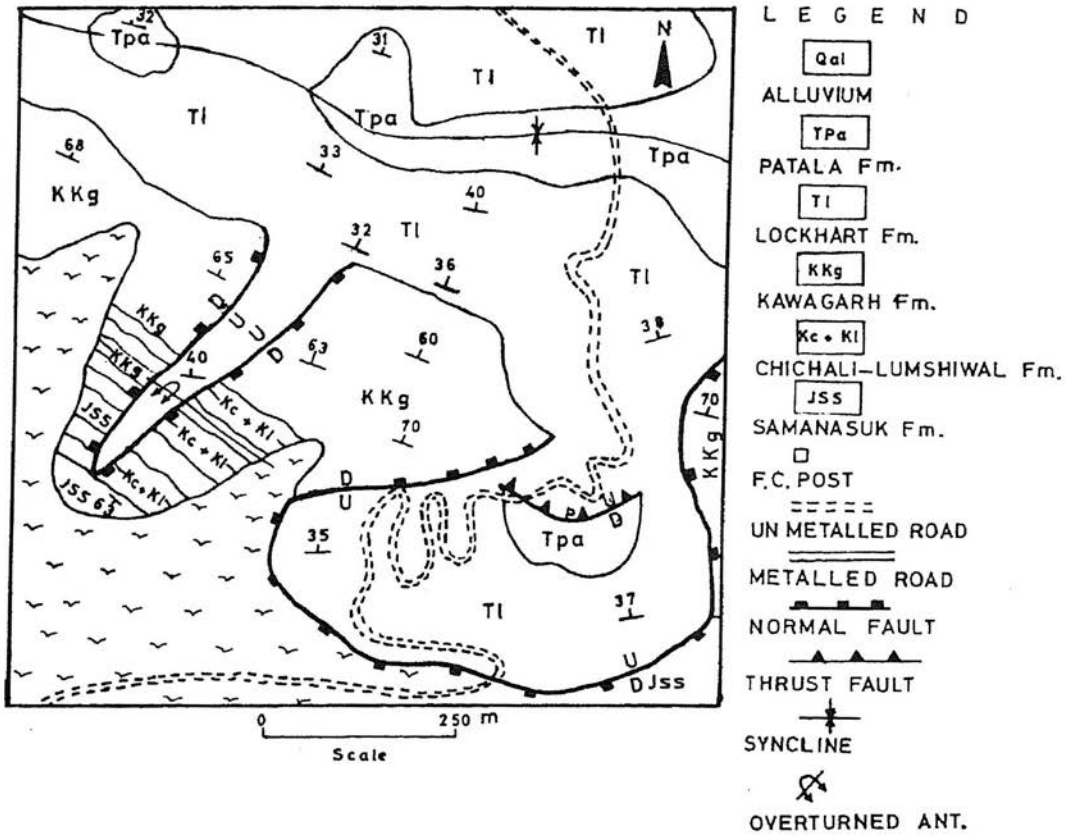

Fig. 5. Geological map of the southward projecting lobe-shaped, tectonic blocks of Paleocene strata resting tectonically on top of the Mesozoic succession (modified after Ghauri, et al. 1983).

blocks. Our interpretation about the initiation and subsequent movement on these south-verging fault structures have been portrayyed in (Fig. 7a,b), together with their relationship to their host fold structure.

We, however, do not believe in the entirely reverse sense of movement of the faults at the base of the southward projecting tectonic blocks comprising Paleocene strata. The shallow, southward dip of these faults, together with a considerable displacement of younger strata on top of the steeply dipping Mesozoic succession would favour a normal sense of movement on these faults. We interpret that southward, up-dip movement of the Paleocene strata out from the core of the synclinal fold resulted in an abnormal uplift of the Kotal Pass area (Fig. 7c). This led to initiation of southward dipping normal faults, along which there was a gravitational collapse of the uplifted Paleocene strata. Abundance of fault breccia associated with the fault planes suggests a near-surface level of these late stage normal faults.

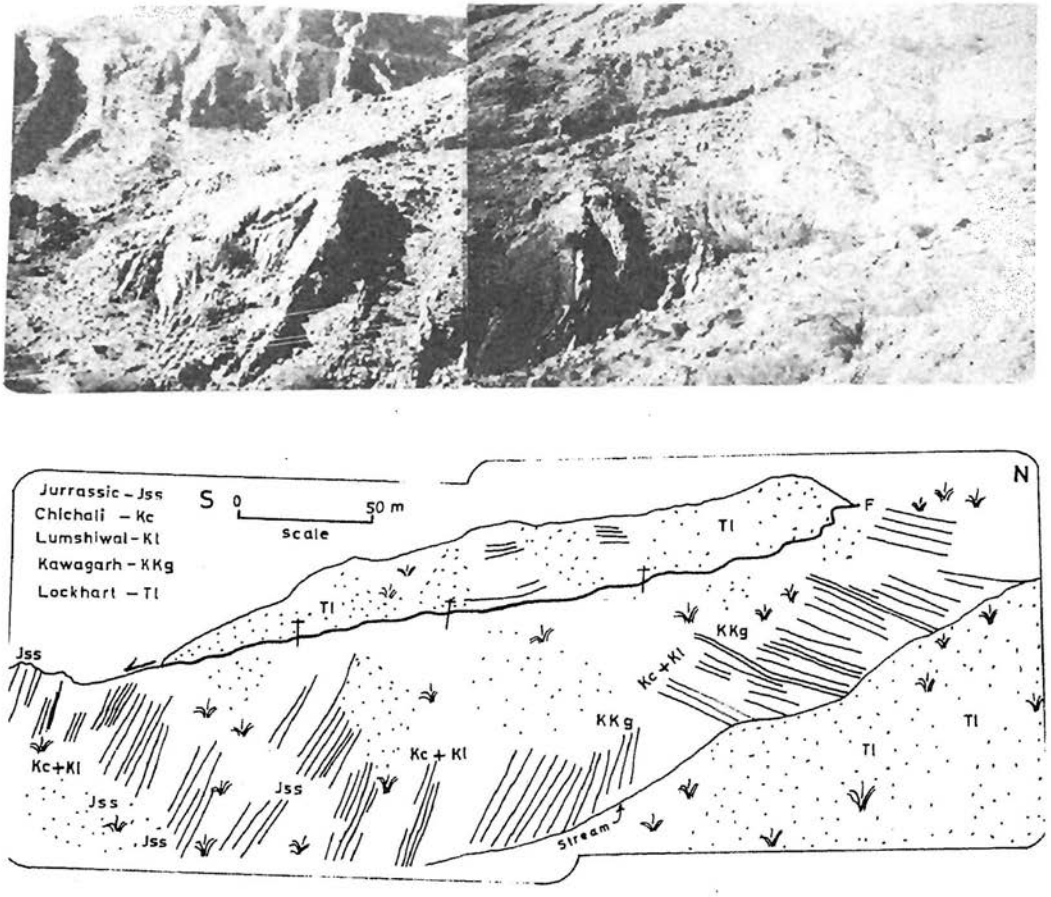

Fig. 6. A view of western lobe-shaped tectonic block of Paleocene strata, resting on top of steeply dipping Mesozoic succession along a normal fault. Note the repetition of Samana Suk-Chichalli-Lumshiwall sequence due to folding and imbrication.

CONCLUSIONS

The Kotal Pass area of the Kohat range shows evidence of latest structures associated with the MBT zone. The early-stage thrust and fold structures in the hangingwall of the MBT resulted in the formation of box-shaped folds with tight overturned limbs. One such syncline at Kotal Pass is characterized by several south-verging out-of-the syncline-thrust faults, which resulted in an abnormal uplift of the Kotal Pass area. This was compensated by the development of southward dipping shallow normal faults, along which there was a gravitational collapse of the uplifted Paleocene strata.

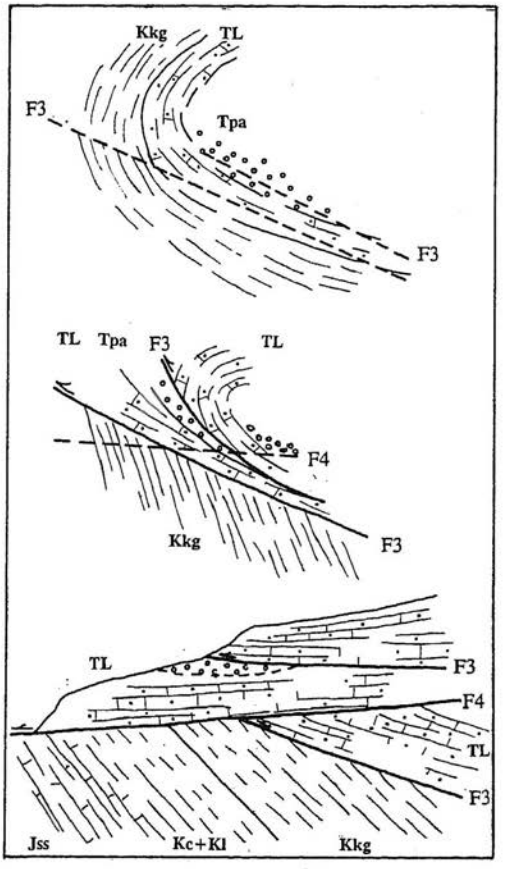

Fig. 7. A schematic representation of the successive stages involved in the development of post-folding fault structures in the Kotal Pass area of the Kohat Range (not to scale). a) development of the overturned limb of the Kotal syncline, with positions of the out-of-the-syncline thrust to be shown by F1 & F2. b) southward displacement of the shallow-dipping strata from the core of the syncline on top of the steep limbs of the syncline. Also shown is the position of the fault (F3) which, in the next stage, marked the gravity collapse of the abnormally uplifted terrain in the Kotal Pass area. c) development of south-verging normal fault, which displaced abnormally uplifted Paleocene strata (out-of-the-syncline thrust in stage b), downward on the southern limb of the syncline. Jss = Jurassic Samana Suk Formation, Kc = Cretaceous Chichali Fm, Kl = Cretaceous Lumshiwall Fm, Kkg = Cretaceous Kawagarh Fm, Tl = Tertiary Lockhart Fm, Tpa = Tertiary Patala Fm.

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