

# GEOTECTONIC EVOLUTION OF KOHISTAN

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## ABSTRACT

Kohistan Zone is located on the north-western tip of the Himalaya and constitutes a tectonic unit in the Indo-Pakistan-Eurasia suture zone between Himalaya and Karakoram. Its characteristic nature distinguishes it from the surrounding well known geological provinces of Hazara and Kashmir on one side and Gilgit, Baltistan and Chitral on the other side. Most of Swat and Dir belong to Kohistan alongwith the southern part of Gilgit, Chitral and northern Hazara.

The Kohistan Zone is bounded by two megashears: the Hini-Chalt-Yasin-Drosh fault lying to the north, which extends into Baltistan through Tissar-Hashupa in Shigar Valley and Machelu in Shyok Valley. Another is recently deciphered Main Mantle Thrust traversing the southern periphery of Kohistan.

In addition, there exists a series of late thrust tectonic features, the two prominent among them being the Hazara syntaxial bend located on the south and a dominant Naze of Nanga Parbat - Haramosh massif on the northeast, which was considered by Wadia to be a horst of the Indian Peninsula, but the author interprets it as a transverse antiform fold.

These major tectonic features, located in the vicinity of the Kohistan Zone, have played a major part in the evolution of its structural history. A chronological account of various tectonic episodes is presented in this paper.

## INTRODUCTION

Kohistan, located near the western terminus of the Himalaya, has been recognised as one of the tectonic zones of the Karakoram by Desio (1964). The

major tectonic features of this region are exposed in the provinces of Dir, Swat, Hazara, Chitral and Baltistan, which have imparted deep imprints in evolving the structural history of Kohistan.

The tectonic events responsible for these deformations began with Eurasia-Indo-Pakistan collision and continued throughout the long span of the Himalayan orogeny, attaining to their peak during Miocene - Pliocene time. An attempt has been made in this paper to classify these major structural features and the tectonic events responsible for the evolution of Kohistan.

### PALAEO-GEOLOGY DURING ARC FORMATION

The Kohistan Zone, which also includes some of the southern parts of Gilgit, Baltistan and Chitral, because of its mafic composition and continental type thickness of its crust has been considered to have originated as a calc-alkaline island arc, as a result of the subduction of former Tethyan crust. Since the end of the Jurassic, when the Indian continental block had drifted closer to Eurasia, the shrinking Tethys was confined to two linear basins, one located on the north of Kohistan bordering Eurasia and another stretching on the south, bordering the Indo-Pakistan continent. The Central area, which remained active during the greater part of the Mesozoic until pre-middle or lower part of the Upper Cretaceous and fed these basins, was the Dras/Panjtal volcanics located towards the northeast in the Ladakh area, western part of Kashmir. The non-plutonic part of the Kohistan sequence derived its material from these volcanics, and constitutes thick stratigraphic sequences in Baltistan, Chitral and Gilgit and to a lesser extent in northern Swat and Dir. This sedimentation continued with the start of Cretaceous and ended somewhere towards Middle Cretaceous.

Palaeontological evidence, derived from a joint geological expedition to Gilgit and Chitral with J. A. Talent of Macquarie University, Australia, may provide significant additions to the chronology of events in the interplay of continental margins in northern Pakistan.

The sedimentary volcanic associations along Hini - Chalt - Yasin - Drosh belt (the northern Tethyan basin) suggest a volcanic arc with a platform area to the northwest, with volcanic materials fed, partly as turbidites (eg. at Yasin), into the "rear arc" basin. These possibly does not include the red-bed sequences present at Reshun and Mir Kani in Chitral. From palaeontological evidence, marine conditions in this basin were terminated during the early Upper Creta-

ceous. There is no evidence, notwithstanding early suggestions for the presence of post - Middle Cretaceous sedimentation, marine or non-marine, along this belt.

In contrast to the above, marine conditions seemingly persisted into the Early Eocene and conceivably, latter on, the southern margin of the basin, as suggested by the presence of typical fossils like Actinocyclus, Discocyclus and Nummulites ataticus in the calcareous bands in the green slaty shales which are associated with the Utror/Dir volcanics (Kakar - 1971, Jahanzeb - 1972). On the basis of this field evidence, their observations created a scenario of Kohistan in which an end to marine conditions occurred during the Upper Cretaceous in the northern part of basin and sometime post Early Eocene in the southern part. If the region between these two belts can be shown to include rocks of pre-Cretaceous age, a case could be made for at least two broad sequences of impactive events, perhaps involving accretion of a micro-continent (plus island arc) towards the close of the Middle Cretaceous, followed by the main continent-continent collision commencing some 55-60 million years later. This view is in accord with the events elsewhere around the margins of the Indo-Pakistan continent but lags with some constraints because of the incomplete history of Indian plate tectonics coupled with lack of palaeomagnetic evidence.

Subsequent investigations conducted jointly by Tahirkheli *et al* (1976, 77) have brought to light further field evidence which has enabled to a new constructions to be placed on the palaeogeological conditions and tectonics during and after the formation of the Kohistan island arc. This has resulted in the production of a new structural model of Kohistan in the context of plate tectonics, which also incorporates the views of the earlier workers.

## NANGA PARBAT MASSIF AND KOHISTAN

Nanga Parbat located on the northeast of Kohistan shows a sharp looped bend in the rocks, which are involved in a thrust around a gigantic cone, the highest peak of which is Diamir (816 m). Many geologists consider this anomalous tectonic feature to be the western terminal spur of the Himalayan Range. But its NNE orientation from the ESE of the Himalaya is quite distinct which does not appear to have a continuity. Desio (1964), on the basis of these observations, considers the Nanga Parbat - Haramosh looped massif as an individual orographic and tectonic unit, constituting a tightly folded anticlinal structure of late phase and enveloping middle to high grade metamorphic rocks.

The sequential order of the rocks exposed in this anticline along the Indus Valley road between Skardu (east) and Gilgit Valley (west) is given below to indicate the grade of contemporaneous metamorphism in Nanga Parbat-Haramosh structural loop. The rocks are listed from the eastern limb (Skardu side) to the western limb (Gilgit side) of the anticline.

1. Muscovite schists, garnet schists and biotite schists; the last being more common.
2. Para-gneisses and associated mafic pyroxene granulite.
3. Biotite-gneisses with granodiorite intrusions.
4. Amphibolite occurring within the loop and intruded by diorite on the western flank of the fold. Other intrusives being porphyritic granite, pegmatite, aplite and vein quartz, listed in decreasing order of abundance.
5. Nanga Parbat gneisses, largely biotitic and forming the base of the anticline. Some are sillimanite-bearing, as indicated in the gneisses in the south in Kaghan Valley.
6. Again amphibolite, the continuation of the one recorded in 4, forming the contact zone of the Main Mantle Thrust and considered to be genetically related to the Dras/Panjal volcanics in Kashmir.

The lithological units involved in the Nanga Parbat - Haramosh anticline described above, extend southward as indicated also in Desio's map (1964), and are well exposed in the south between Babu Sar Pass and Gitti Das which form the eastern edge of the Karakoram Zone. Here the deformation is rather more intense. Isolated associations of peridotite bodies are also recorded with these rocks in the Main Mantle Thrust Zone south of Chilas, in the upper reaches of Thak Valley in Babu Sar Pass and in the northern fringe of Kaghan Valley, bordering Kohistan between Bata Kundi and Kaghan town.

The eastern tectonic line of the upper Indus suture zone outlined in Tsang Po and passing through Ladakh and Astore, after the swing around the Nanga Parbat-Haramosh massif remained uncertain for want of support from field evidence. Some previous workers suggested the Chalt-Yasin-Drosh megashear as the extension of the Indus suture zone.

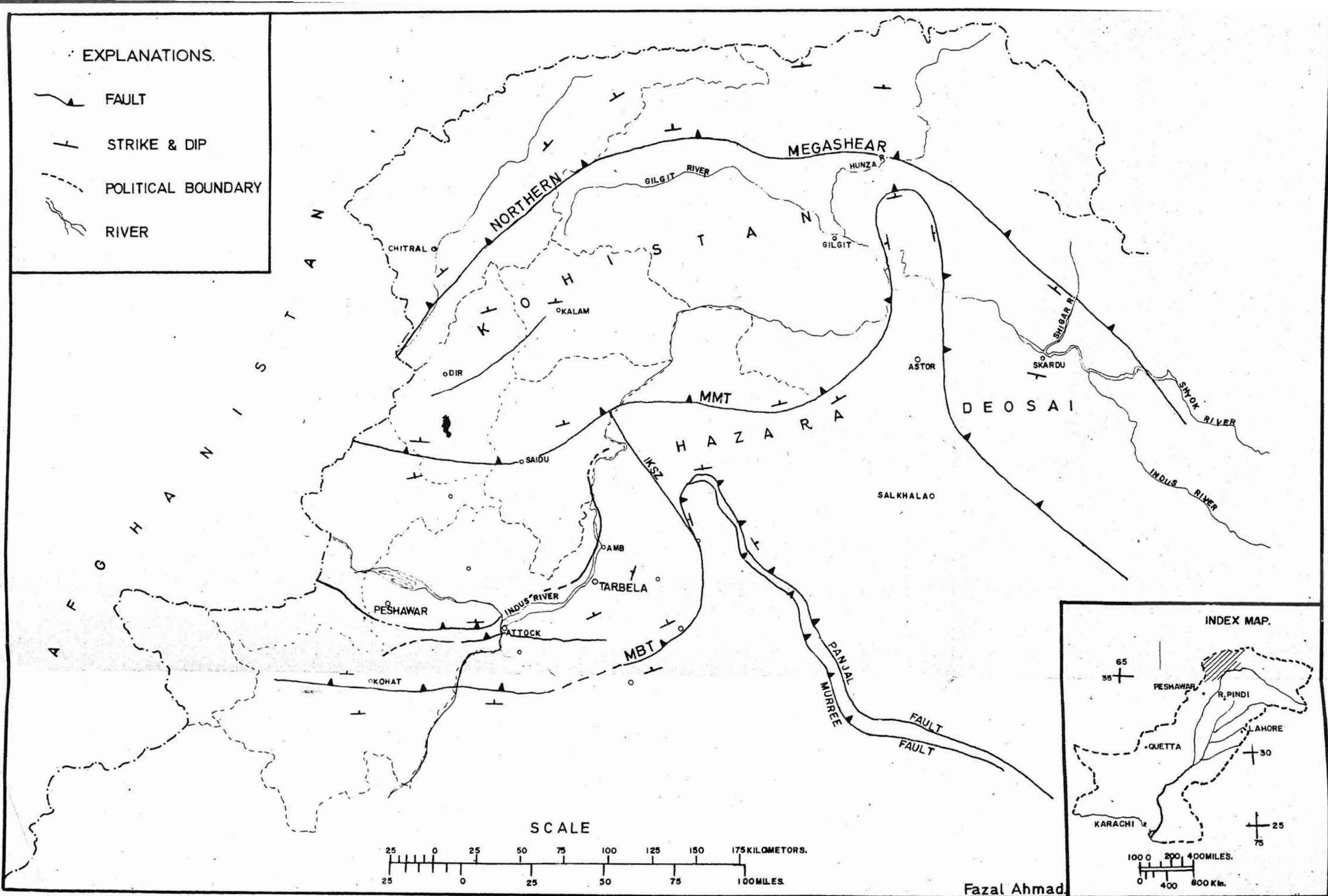


FIG.1 KOHISTAN ISLAND ARC AND SOME ASSOCIATED MAJOR STRUCTURAL FEATURES

Tahirkheli *et al* (1976) identified another mega-thrust called the Main Mantle Thrust (MMT), which passed through the southern periphery of Kohistan and its westward extension traverses Dir, Swat and Bajaur, west of Nanga Parbat. This thrust has been delineated in the east up to Babu Sar Pass with a NNE swing towards Chilas. Recent investigations have confirmed the connection of MMT with the Indus tectonic line looping around Nanga Parbat-Haramosh massif.

This suggests that a symmetry exists in the general tectonic pattern of the eastern tectonic line and the MMT in Kohistan, as a result all the major folds, faults, and formational contacts follow this structural trend. In the adjacent Hazara area on the south of Kohistan this tectonic translation has been affected by the Hazara syntaxis.

### HAZARA - KASHMIR SYNTAXIS AND KOHISTAN

The Hazara-Kashmir syntaxis, located to the south of Kohistan, constitutes a great regional bend which has caused inflection of the rocks of the western Himalaya and Hindu Kush. According to Wadia (1931), this syntaxial flexure is the result of compressional folding about a naze of Indian shield which has involved the entire width of the Himalayas for over 200 km, in the north. Gansser (1964) considers that the bending of western Karakoram from ESE-WNW to the E-W trending Hindu Kush is the reflection of the northern syntaxis. The translation due to structural impact of the Hazara syntaxis in the Gilgit area is also discussed by Stauffer (1968), who cites the regional SW-SE trend of the Gilgit-Hispar area as a part of the eastern limb of the structural arc concentric about this bend.

Kohistan is located between the Hazara syntaxis and the extreme northern part of the western Karakoram, thus the impact of this bending on the rocks is very pronounced. Structural deformation such as tension lineation, foliation, and banding in the Kohistan sequence are usually parallel to the movements on the Main Mantle Thrust. Mattauer *et al* (1975, 1977) consider such deformation to have been produced by large scale simple shear in the N-S direction, analogous to those characterizing the MCT in the Central Himalayas or the "Schistes lustrés" thrust sheets in Corsica and the Western Alps. This deformation in Kohistan reflects the remnants of the earlier forces which were generated during the Asia-Indo-Pakistan collision in the Early Tertiary period.



The second phase of deformation in Kohistan, which was responsible for creation of Nanga Parbat anticline is denoted by the occurrence of large N-S striking folds and are solely responsible for the local vertical dipping of the previous foliations. The deformation gave final shape to the Hazara syntaxis during the post-Middle Miocene period, which according to Tapponnier and Molner (1977) is related to lateral squeezing of the NW tip of India after collision with Asia.

This deformational phase has also affected the Main Mantle Thrust, as a result, the surface features of the thrust have become blurred making its interpretation in the field rather difficult. The northward swinging loop in the MMT, in the vicinity of Pattan, may also be attributed to the second phase. The Nanga Parbat-Haramosh dome, as earlier described, is another major structure in the vicinity which is considered to be the result of the later deformational phase.

The broad arc-type structural loop on the north of the syntaxis in Karakoram and Hindu Kush, on which the views of earlier workers have been recorded, is related to both phases of deformation. After the continental collision, during the late Eocene or Early Oligocene, lateral squeezing caused the bending in the rocks to start developing alongwith the syntaxis during the first phase. Translation of stresses during this period may not had much effect because the syntaxis was itself in course of formation and it is probable that most of the shocks were absorbed during its folding and thrusting. However, it is to be expected that some stresses were translated to the immediate surroundings of the syntaxis, thus affecting the rocks of Kohistan, Kashmir and western Karakoram, lying to north, east and west respectively.

The Murree clastics, considered to have been deposited during the Middle Oligocene-Middle Miocene period are involved in the syntaxial bend. Thus it is to be expected that whilst the earlier deformation was in progress, the Murrees were in process of deposition. The second phase of deformation, started during the post-Middle Miocene period when, due to uplift of the basin during the earlier deformation, the sedimentation receded. The syntaxial configuration reached its zenith during this period, when the deformation was transmitted to the far north, thus involving the Karakoram and Hindu Kush ranges, and producing a uniform concentric bending around the syntaxis.

## MAIN BOUNDARY THRUST AND INDUS KOHISTAN SEISMIC ZONE

The Main Boundary Thrust has special significance for Kohistan, because seismo - tectonic investigations of Hazara and the adjoining region have yielded informations on deep crustal tectonic alignment between the MBT with Pattan, in Kohistan.

The MBT is variously named in different parts of the Indo-Pakistan Himalaya by the earlier workers as the Murree thrust, Krol thrust and Riasi thrust. All these thrusts demarcate a continuous boundary between the post - collisional Murree and Siwalik formations and the pre-collisional crystalline rocks along the entire Himalayan belt.

The Main Boundary Thrust, after traversing through Kohat, south of Kala - Chitta Range and the western parts of Azad Kashmir, enters Hazara on the SE and becomes involved in the Hazara - Kashmir santaxial bend. Recent work relating to deep crustal displacement resulting in major tectonic features in Hazara and Kohistan, based on micro- and macro-seismic data has been carried out at the Tarbela Seismic Observatory. Some of these results do not correlate entirely with the surface geology, but their application to the development of an acceptable model to explain the regional structural problems is undoubtedly valuable. Thus, both the major surficial structural features of the area and deep crustal faults considered relevant as having a direct bearing on Kohistan, will be taken into account. Armbruster *et al* (1978), Seeber and Jacob (1977) and Pennington (1974), on the basis of seismo-tectonic studies of Hazara and Kohistan, consider the MBT west of the syntaxis to have an underground extension to the north, towards Kohistan at a depth of 10-12 km, as a decollement of sedimentary prism. They have called this fault the Indus Kohistan Seismic Zone (IKSZ). On the basis of the nature of its composite fault plane solution, the IKSZ is a thrust which is locally seismically active, and the epicentre of the Pattan earthquake of 1974 was located in this zone.

Concerning exposed geological features, between the western limb of the syntaxis and the IKSZ, the Murree Formation, involved in the MBT, is not recorded as extending northwestward. Instead the fault trace of the MBT, after the loop around the syntaxial bend, continues south-westward, more or less following the Kunhar River with a NE - SW strike, which is parallel to the general structural trend of the rocks exposed on the southern periphery of the Kohistan zone.



The Indus Kohistan Seismic Zone, as an extension of the MBT, as indicated by Armbruster *et al* and others therefore requires to be treated independently. It is likely that the seismically confirmed deep crustal dislocation called the IKSZ, may be a separate fault with a NNW-SSE trend, connecting the Hazara syntaxis with the MMT in the vicinity of Pattan. This fault, therefore, is younger in age than the MMT and could be created by the events responsible for the formation of the syntaxial bend during the post-Middle Miocene period. Thus, the possible extension of the IKSZ, southwest of Pattan, may actually be the trace of the megashear MMT, which traverses through Pattan, Dubair, Shangla, and extends westwards through Zulum and Khar in Dir, coinciding with the seismically confirmed deep crustal trace of the Indus Kohistan Seismic Zone.

### SOUTHERN MEGASHEAR: MAIN MANTLE THRUST

The megashear MMT, which is aligned with the Nanga Parbat-Haramosh tectonic line on east, spans an area of about 400 km through Diamir, Kohistan, Swat, Dir and Bajaur, before entering Afghanistan. The general trend of the MMT is NE-SW and it is located along the contact of the mafic/calc-alkaline meta-igneous rocks and the metasediments belonging to the Indo-Pakistan continental mass. Along this mega-thrust, the igneous rocks have over-thrust the metasediments to the south over a 10-15 km wide zone. The thrust is also manifest as the broad high topography of Kohistan relative to Hazara, adjacent to the south.

In addition, numerous auxiliary fractures are developed along and across the thrust; frequent brecciation and mylonitization are also observed along the contact. One such occurrence lies 3-4 km north of Jijal along the Karakoram Highway, where serpentinite is found containing many pyroxene fragments. Geophysical investigation, carried out in the vicinity of Alpuri and Shangla in Kohistan, (Saleem, 1969) has also confirmed this tectonic break.

The thrust zone exposes high density rocks such as peridotites; these are mainly harzburgites with websterites, diopsidites and garnet-pyroxenites, which have been tectonically emplaced from the upper mantle. The high pressure granulite facies rocks commonly of garnet - diopsidic pyroxene - ca/plagioclase - zoisite - rutile, are associated with the thrust in the Indus Valley between Jijal and Pattan. Besides, hypersthene granulites of Jan (1977) of gabbroic origin extends in a vast area in Swat and Dir.

Glaucophane schist occurrences in metasediments reported in the vicinity of Topsin and Shangla Pass (Shams-1972, Desio-1974), are also recorded in isolated pockets in the vicinity of Babu Sar Ulla and west of Saidu in Swat and Dir, which confirms high pressure metamorphism in the MMT zone on the subducted Indo-Pakistan plate. The upper part of the Besham Group containing blue-schists occurs very close to the contact with the mafic and ultramafic igneous rocks and coincides with the surficial trace of the Main Mantle Thrust.

To distinguish the megashear from the other thrust such as, MBT and MCT in the Outer and Central Himalayas, this thrust has been named the Main Mantle Thrust to signify its association with the high density mantle derived rocks.

#### NORTHERN MEGASHEAR: MACHELU-HASHUPA-HINI-CHALT-YASIN-DROSH FAULT

The Hini-Chalt-Yasin-Drosh fault is another mega-thrust which passes through Gilgit and Chitral and encircles the Kohistan zone on the north. During recent investigations in the northern areas, this thrust has been extended through Hashupa in Shigar Valley and Machelu in Shyok Valley in Baltistan. Its general trend swings between E and ENE at low to medium dips towards the N and NNW.

This fault has been investigated in various sections in Chitral, Gilgit and Baltistan and revealed to be a low angle thrust. It is seismically active and contains a large number of epicentres which has given rise to several low to medium intensity earthquakes in the past.

In Baltistan, in three sections, Tissar, Hashupa and Machelu, the northern mega-thrust lies along the contact of Greenstone Complex (Cretaceous) and Darkot Group/Dumordu Formation of ? Permo-Carboniferous age; the latter has overthrust the former to the south. In these sections the rocks equivalent to Yasin Group representing the youngest Tethyan remnant in the northern region are missing, which being thin, may have been disrupted by faulting.

At Chalt, the fault lies at the contact of the Darkot Group/Dumordu Formation and Greenstone Complex, the Yasin Group is missing in this section too. Ivanac *et al* (1956) mentioned this fault as a low angle thrust. At Yasin, the Yasin Group and Greenstone Complex have been overfolded and have thrust over by the older Darkot Group to the south with a displacement of over six km.

From Yasin, the fault extends westward along the contact of Darkot and Greenstone Complex, at places isolated patches of rocks belonging to Yasin Group also occur along the thrust plane. In the Laspur area, near Gilgit-Chitral border it has been traced NE of Sandur Pass, in the vicinity of Baruk village.

The Greenstone Complex, which is intimately associated with the northern megashear in Gilgit and Baltistan has not been examined thoroughly in Chitral and was left undifferentiated by earlier workers. Stauffer (1975) and Calkins *et al* (1969) briefly mentioned these rocks in Chitral and called them Greenstone Volcanics, which they mapped as a part of the Chitral Slate.

Among the earlier workers Tipper (1924) recognised two major faults in Reshun Gol, which placed the Reshun Formation, (Cretaceous to lower Tertiary) in direct contact on one side with the Devonian carbonate rocks and on the other side with the Chitral Slate belonging to the Asiatic Mass. Stauffer has provided an elaborate interpretation of these faults postulating a 200 m thick thrust block consisting of isoclinally folded Reshun Formation rocks which have over-ridden the Palaeozoic metasedimentary rocks of the Chitral Slate. In the upper thrust, according to Stauffer, the Reshun Formation is in turn overthrust by a 5000 m thick sequence of limestones and quartzites of Devonian-Carboniferous age.

In Chitral, the northern megashear follows the course of the Reshun Formation, which has a quite widespread distribution, and extends westward from the Gilgit border through Reshun and Shishi Gol north of Drosh. The Reshun Formation in Chitral has been correlated with the Yasin Group of Gilgit by earlier workers which has been assigned a Cretaceous-Lower Tertiary age.

The rocks of the above-mentioned groups which are associated with the fault zone on Eurasian platform constitute slates, quartzites and limestones showing varying degrees of metamorphism from south to north. In the Reshun Formation and Yasin Group, which are the youngest in age, the rocks retain their sedimentary character.

Among the igneous, mafic/volcanic rocks, associated with the island arc in the vicinity of megashear, there are quite frequent occurrences of tectonically emplaced serpentinite, and basalt, andesite, trachyte and rhyolite, with agglomerate and banded tuffs. Pillow structures are commonly present in the volcanics. Vertically the volcanics span the sequence from Greenstone Complex to Yasin Group, having abundant distribution in the former.

## METAMORPHISM

South of the Main Mantle Thrust, on the Indo-Pakistan platform, Hazara Slates, Tanawal Quartzites and the Abbottabad Formation in Hazara and their equivalents west of the Indus River have widespread distribution. They range in metamorphic grade from slaty shales to phyllitic schists, sandstones to quartzites, and semi-to medium- crystalline limestones. Thus the grade of metamorphism in these areas is generally low except in the vicinity of more highly deformed areas or close to the igneous intrusions, where minerals of a higher metamorphic grade are locally developed. Towards the north, within a radius of 20-30 km from the MMT, between Besham and Dubair and Thakot and Banna, two easily accessible sections in Hazara have been investigated in detail and the rocks seem to be more highly metamorphosed; these include marble, garnet-mica schists, biotite schists, staurolite schists, graphitic schist, kyanite schists, para-amphibolites and orthogneisses, suggestive of a progressive increase in metamorphism from the south towards the MMT in the north. Between these two meso-katazonal series, a greenschists/blueschists slice, some tens of meters thick has been recognised along MMT over more than one hundred kilometers.

The westward extension of the Besham Group in Swat and in the Jandul Valley of Dir, contains amphibolite facies rocks showing a marked increase in metamorphic grade.

On the northern side of the MMT, the metamorphic effects on the mafic, calcalkaline igneous suite are demonstrated by amphibolite and granulites facies paragenesis associated with the presence of lineation, foliation and banding. These structures are parallel to the MMT and have a variable impact on the rocks throughout Kohistan, being more pronounced in the vicinity of the thrust zone.

## KOHISTAN UNDER THE CONTEXT OF PLATE TECTONICS

The geology of Kohistan is unique in the area in containing widespread, mafic and calc-alkaline suite of rocks covering nearly three-quarters of its area. The presence of these rocks gives a distinct character to the geology of Kohistan relative to the surrounding well known geological provinces of Hazara, Kashmir Swat and Dir (Indo-Pakistan Mass) and Baltistan, Gilgit and Chitral (Asiatic

Mass). This typical sequence in Kohistan, because of its composition and thickness does not fit either in an ophiolite suite or as a segment of oceanic or continental crust. Rather, its composition could conform to a complete cross-section of a calc-alkaline island arc associated with the subduction of the former Tethyan crust.

The mafic and calc-alkaline rocks, as discussed earlier, have been overthrust to the south onto folded and metamorphosed Besham Group rocks of presumably Palaeozoic age. This thrust lies along the contact of pyroxenites and peridotites with specific gravities up to 3.3 or 3.4 which are the transported tectonic slices from the upper mantle. The lavas in the upper part may be compared with the volcanics of present day active area. The remaining meta-gabbros/norites and part of the amphibolites, which make up the bulk of the sequence, could be large calc-alkaline plutons intruded into the remnants of the oceanic crust.

The Main Mantle Thrust block has an association of high density upper mantle rocks, whereas the northern megathrust contains serpentinite among the ultramafics, with basalt, andesite, trachyte and rhyolite in the volcanics. The pillowed structures in these volcanics suggest an origin under oceanic conditions.

The tectonic evolutionary history and other typical geological features of Kohistan are not identical with other parts of the Himalayan belt. Firstly, there is no reported occurrence of basin and arc formation elsewhere, such as occurs in the western segment of the Himalaya, between Nanga Parbat and the Afghanistan border. However, east of  $80^{\circ}\text{E}$ , a single Early Tertiary suture zone has been recognised in the Central Himalaya by Gansser (1964). North of the suture, the Transhimalayan granites and Calc-alkaline volcanics appear to be associated with the Cretaceous subduction of the Tethyan ocean floor beneath an Andean type margin. Further to the west, the "Ladakh Batholithic zone" may represent the east-west transition from one type of active margin to the other. According to Mattauer (personnel communication), the existence of two distinct ophiolitic thrust sheets emplaced from NW to SE in Afghanistan may be interpreted in terms of back-arc spreading. However, there appears to be a major difference between these rocks and those of Kohistan. In the former, between the two sutures, the intermediate block is sialic whereas in the latter it is calc-alkaline.



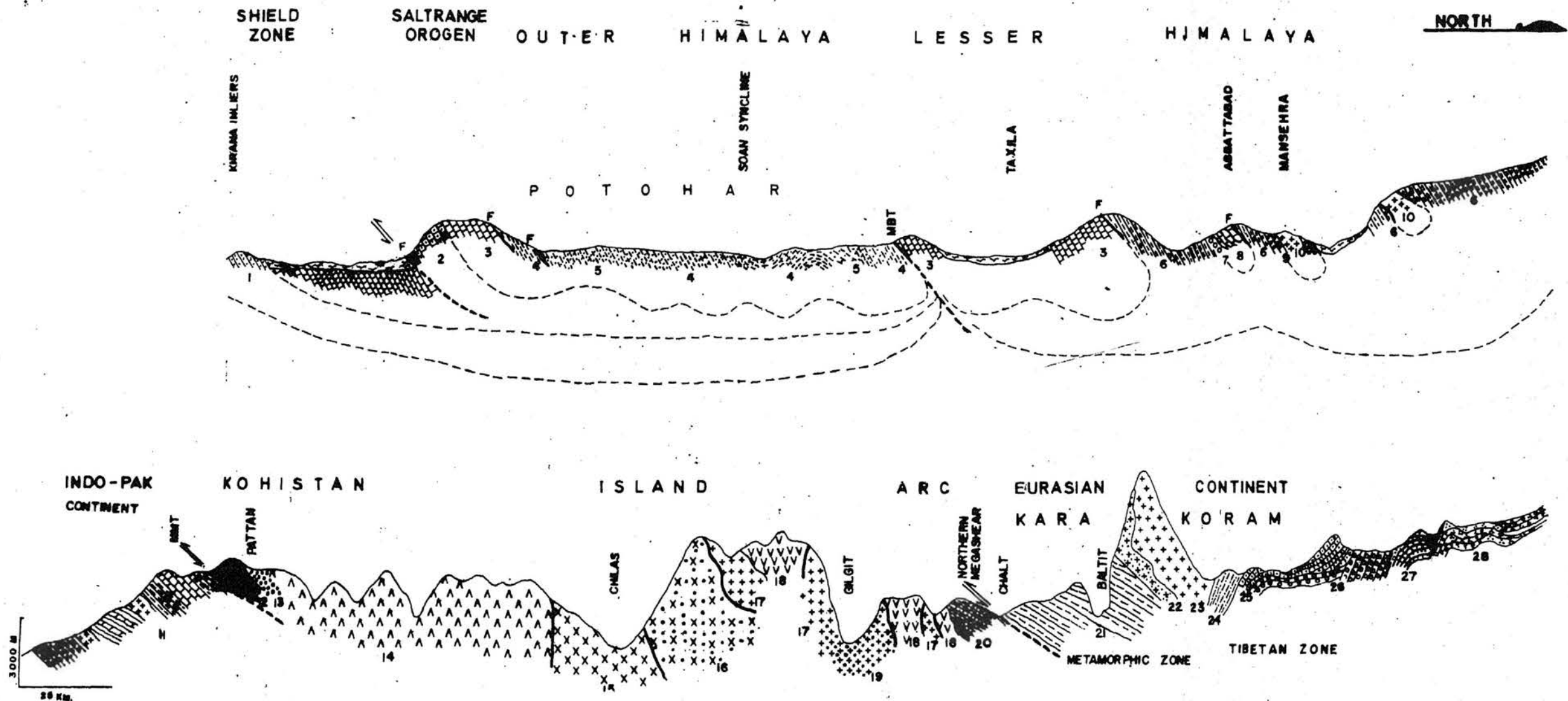


FIG. 2

# GEOLOGICAL PROFILE SHOWING ADJUSTMENT OF KOHISTAN IN THE TECTONIC FRAMEWORK OF INDO-PAKISTAN AND EURASIA PLATES IN NORTHERN PAKISTAN

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1. SHIELD ROCKS 2. INFRA-CAMBRIAN-CAMBRIAN-UPP PALAEOZOIC FMS. 3. MESOZOIC-LOWER TERTIARY FMS. 4. MURREE FM. 5. SIWALIK GR. 6. HAZARA SLATES
7. TANAKKI BOULDER BED 8. ABBOTTABAD FM. 9. TANAWAL FM. 10. MANSEHRA Gr. 11. BESHAM GROUP WITH FOLIATED Gr. BODIES 12. JIJAL COMPLEX 13. PATTAN GARNET-GRANULITES 14. KAMILA AMPHIBOLITES 15. BAHRAIN PYROXENE GRANULITES 16. BESHAM DIORITES WITH MAFIC BODIES 17. KOHISTAN Gr. 18. GREENSTONE COMPLEX 19. KOHISTAN Gr. WITH BASIC AND MAFIC BODIES 20. CHALT FM. 21. DURMORDU FM. 22. MIGMATITIC GNEISSES 23. KARAKORAM GRANODIORITE 24. PASSU SLATES 25. GUJAL DOLOMITE 26. GIRCHA FM. 27. KILIK FM. 28. MISGAR SLATES



In the past, the pioneer work of Griesbach (1891), Diener (1895) and Gansser (1964), outlined the main suture zone between the Indian and Asian continents, north of the eastern Himalaya along the Tsang-Po and Indus Valley, as a belt of flysch, volcanics and ophiolites. This belt could be traced westwards through Ladakh and Astore to Nanga Parbat. Beyond this point, controversy exists on the extension of the Indus suture and various schools of thought have presented their views with the support of geological and geophysical data gathered during recent decades.

Crawford (1974) considered the Indus suture line to be relict fracture extending down to the mantle but he did not consider this junction to be the boundary between the Asia and Indo-Pakistan plateforms. Crawford traced the junction between the continents beyond Tibet on the northern side of the Tarim Basin block and the Tienhan. To support his contention he cites Permo-Triassic vertebrate fossils showing Gondwana affinities found in Tienhan and the Turfan Basin. Another school of thought considers the Indus suture ophiolites to be in continuity with those of the Baluchistan arc, which mark the limits of the northern platform. Others believe this boundary to extend west of Nanga Parbat through the Karakoram and Hindu Kush, a line has yet to be drawn to demarcate the junction.

Recent studies have revealed some new evidences on the geology and structural history of the western tip of the Himalaya, which have helped in the preparation of a tectonic model to define a collisional zone in the northwest Himalaya, west of Nanga Parbat.

The Hini - Chalt - Yasin - Drosh megashear has since long been considered to be the "traditional" extension of the Indus suture zone, west of Nanga Parbat. Further west, in Afghanistan, two suture zones, have been identified which are separated by the sialic block of Kabul. According to Mattauer as mentioned earlier, this may have resulted as a result of back-arc spreading.

## CONCLUSIONS

The identity of Kohistan as an island arc on the northwestern tip of Karakoram has replaced the old concept of a single suture, west of Nanga Parbat. A new theory has emerged, based on extensive field investigation carried out jointly by the members of Montpellier and Peshawar Universities,

providing a new tectonic model of Kohistan and the associated suture zone in the context of global tectonics. According to this model, there exist two suture zones indicated by two megashears; one extends along the northern boundary of Kohistan island arc (Machelu - Hashupa - Hini - Chalt - Yasin - Drosh) and the other recently deciphered, is the Main Mantle Thrust girdling the southern periphery of Kohistan and bordering the Indian platform. A chronological summary of the major tectonic episodes in Kohistan and the adjoining areas is given below.

After the evolution of the Kohistan Island arc between the Indo-Pakistan and Eurasian platforms, the first major tectonic event was the Indo-Pakistan continent subduction under the Kohistan arc about 60-70 million year ago. A subsequent evolution completely closed the Tethys ocean in this region, sandwiching the Kohistan island arc between Eurasia too. The collision resulted in suturing, which produced two prominent tectonic scars on the north and south, representing the zones where Kohistan was welded into both continents. Subsequent stresses, after the merging of India into Eurasia, according to Molnar and Tapponnier (1975), underthrusting pushed from 600 to 700 km of the Indo-Pakistan slab beneath Eurasia, resulting in thousands of metres of vertical thickness of rocks in Himalaya, Tibet and the southern region of China. This deformation is still continuing at the rate of about 4 cm. per year.

Besides, these two megashears and related deformations the other major tectonic features adjoining Kohistan on the NE and SW are: (a) the transverse antiform of Nanga Parbat - Harmosh, and (b) the Hazara syntaxial bend. These tectonic features in the vicinity of Kohistan, originated subsequent to suturing sometime between the Upper Eocene and Miocene, a period which witnessed major earth movements responsible for the tectonic remoulding of the Himalayan belt

The sequential order of deformational phases in Kohistan and the adjoining regions may be summarized as follows :—

- (i) subduction of Indo-Pakistan continent under Kohistan island arc which generated high pressure metamorphism during Upper Cretaceous - Eocene, approximately 60-70 years ago.
- (ii) Suturing: two sequences of impactive events can be recognised. The first involved the Eurasian continent along the northern megashear by underthrusting the Kohistan arc, and the second occurred along

the Main Mantle Thrust in which the Indo-Pakistan plate has under-thrusted the Kohistan arc. The first event is timed during post Upper Cretaceous, whereas the second occurred between the middle and the upper part of Eocene.

- (iii) Formation of a gigantic structural loop around the Nanga Parbat - Haramosh Massif, which originated subsequent to the MMT and played its part in the deformation of the latter.
- (iv) Formation of the Hazara syntaxis during the oligocene - Miocene period. The Outer Himalayan clastics, the Murree Formation, are involved in this bend and were deposited between the Middle Oligocene and Middle Miocene, thus pinpointing this deformation as having reached completion in its present form during post Miocene - Pliocene time.
- (v) Creation of the Main Boundary Thrust between the Higher Himalaya and Lesser Himalaya, involving both the Murree and the Siwalik clastics and dateable as post - Siwalik, perhaps Pliocene in age, some 13-10 million years old.

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