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# A SECTION THROUGH THE NANGA PARBAT SYNTAXIS, INDUS VALLEY, KOHISTAN

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## ABSTRACT

*The Nanga Parbat gneisses show polyphase Himalayan age deformation, the last major phase being the development of large upright folds which form the syntaxial structure. These folds are related to a different kinematic system to the main thrust systems of Pakistan and probably formed due to localised high strain near the pinning point of the Himalayan thrusts at the western end of the Himalayan arc.*

## INTRODUCTION

In the western Himalayas, the Indus suture between the Indian and Tibet plates divides, to form the Northern Suture or MKT (Main Krakorum Thrust) and the Southern Suture or MMT (Main Mantle Thrust) (Gannser, 1964; Bard *et al.*, 1980). These enclose the Kohistan complex, composed of a deformed Cretaceous island arc, which collided with the Tibet block during Albian-Aptian times and was then intruded by calc-alkaline rocks which make up the Kohistan and Ladakh batholiths (Coward *et al.*, 1986; Pudsey *et al.*, 1986). The Kohistan complex, together with the northern (Tibet or Asian) plate, overrode the Indian plate during the Eocene, forming the MMT and the numerous thrusts to the south (Coward *et al.* op cit.). The MMT has a highly irregular outcrop trace on the map and north of Nanga Parbat, it is folded to make the Nanga Parbat syntaxis, which almost completely separates the Kohistan and Ladakh parts of the arc. This paper aims to discuss the nature and significance of the syntaxis as seen in the road section along the Indus valley.

## THE NANGA PARBAT GNEISSES

The main rock types of the Nanga Parbat syntaxis are a series of biotite augen gneises, probably originating from a coarse feldspar porphyritic granite. The gneiss shows intense deformation throughout and is essentially similar in appearance to the Mansehra granite, which is a Cambrian porphyritic granite intruding the Precambrian metasediments of the Indian plate, between Abbottabad and Besham. Within the gneisses there are locally several hundred metre thick slivers of schists, which may have originated as metasediments. They contain garnet schists and gneisses and occasional calc-silicate bands. Similar metasediments were described from near Nanga Parbat by Wadia (1931) and Misch (1949). The gneisses and metasediments contain numerous tightly folded quartzo-feldspathic veins, amphibolite sheets which presumably originated as basic dykes and late muscovite-biotite bearing pegmatites.

The gneisses are easily distinguishable from the adjacent rocks of the Kohistan and Ladakh complexes, which are essentially basic schists with calc-silicates and marbles, intruded by granites, granodiorites and diorites. The age of the Nanga Parbat gneisses is unknown. If they are the same as the Mansehra granites, then they form part of the early Cambrian suite which occurs along much of the Himalayan belt (Le Fort, 1980) and the thin metasediment slivers would be Precambrian relics.

## THE STRUCTURE

The structure is summarised on the map and section in Figs. 1 and 2. The gneisses and metasediments show an intense $F_1$ foliation, formed by alignments of mica and quartz ribbons and the elongation of feldspar augen. This fabric is tightly folded by $F_2$ structures and re-orientated round large upright $F_3$ folds. The change in trend of the gneissic foliation, as seen on the map (Fig. 1), reflects these $F_3$ folds. There are variations in plunge of the $F_3$ folds, giving domal patterns on the map. However the cross section in Fig. 2 shows the form of the $F_2$ structures as determined from changes in small-scale fold sense.

The MMT appears to be an $F_1$ structure, being tightly folded by the $F_2$ folds. These $F_2$ structures dominantly face east and have fold axes approximately parallel to the mineral lineation direction. It is often impossible to distinguish between the mineral lineations and the $F_2$ fold crenulations. The lineations plunge towards 170 +/– 100 and there are locally sheath folds whose strongly curvil-

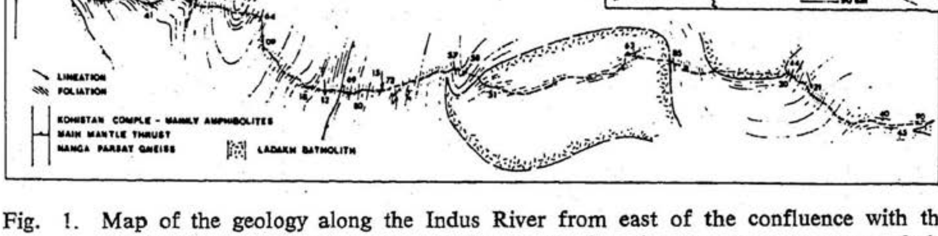


Fig. 1. **Map of the geology along the Indus River from east of the confluence with the Gilgit River, to near Skardu: see inset map for location and summary of the regional Kohistan geology. B — Besham, C — Chilas, G — Gilgit, N — Nanga Parbat, S — Skardu.**

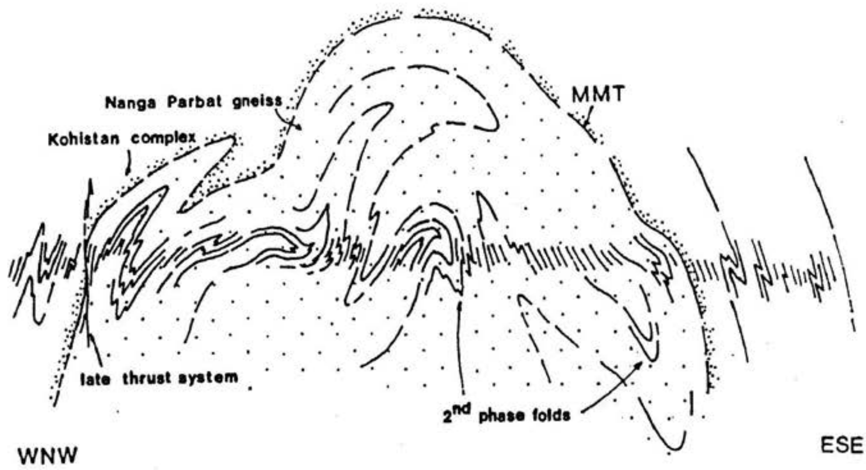


Fig. 2. Cross section through the Nanga Parbat syntaxis, along the Indus valley.

near fold hinges are bisected by this lineation direction. The lineation is thus considered to be sub-parallel to the main shear direction related to the intense deformation. The $F_1$ and $F_2$ structures are probably part of the same general overthrust regime, where the Kohistan complex overrode the Indian plate to the SSE, intensely deforming the gneises, crumpling the sheared gneisses into $F_2$ folds and smearing the fold hinges into the transport direction. The fact that the folds dominantly face towards the east, suggests a dextral shear couple to this overthrusting, where the Kohistan segment was overthrust further than the Ladakh segment (cf. Coward and Potts, 1983). The $F_3$ folds, however, have axes obilque to the earlier lineations and are probably part of a different movement system.

The quartzo-feldspathic veins and amphibolites have suffered all the deformation and clearly show the early isoclinal structures. The late pegmatites, however, post date the upright $F_3$ folds. They are essentially undeformed but they do show gentle warping as though they had suffered a late component of $F_3$ deformation.

The contact between the Nanga Parbat gneisses and the Kohistan complex is a one of intense $F_1$ deformation, but in the west there has been late movement on an upright thrust, producing a several metre wide zone of cataclasite, locally with ultracataclasite.

The Kohistan complex, to the west, shows some evidence of the N–S trending upright folds. In the centre of the Kohistan arc, the volcanics and metasediments show early E–W trending, gently plunging, upright folds, but near the syntaxis the plunge of these structures steepen to almost vertical, that is they have been turned on end by the upright syntaxis structure. To the east of the Nanga Parbat syntaxis, the N–S trending folds are less dramatic, but fold the fabrics in the metavolcanics and intrusive rocks (Fig. 1).

An important aspect of the upright folding is that it allows the footwall to the MMT to be exposed for over 150 km behind its southernmost exposure. The MMT must have overthrust the Indian plate rocks for at least this distance, smearing the granites and metasediments into the intense $F_1$ and $F_2$ structures beneath. This distance of 150 km needs to be added to the estimations of thrust displacement made from balancing cross sections in the frontal thrust systems south of the MMT (Coward & Butler, 1985), giving a total displacement for the Kohistan arc of over 620 km.

## ORIGIN AND SIGNIFICANCE OF THE NANGA PARBAT STRUCTURE

The Nanga Parbat fold is a late, local $F_3$ structure, which trends almost perpendicular to the other major folds and thrusts in Pakistan and the main Himalayan chain (see also Mattauer, 1986). It must therefore originate from some local oblique or transverse movement and it is notable that it lies at the western end of the Himalayan arc (Fig.3). Two origins have been suggested for the arc and the syntaxis (Coward *et al.* in press). The Nanga Parbat fold may have developed from large-scale cross folding, possibly related to the lateral westerly directed spreading of the thickened Tibetan crust. Alternatively it could be due to the pinning of the main Himalayan thrust system in the west and associated rotation around this pinning point. As there seems to be some continuity of structure from Nanga Parbat to the main Himalayan chain, and as there is evidence for rotation of the Himalayan thrust sheets (Klootwijk, 1981), this latter mechanism is preferred.

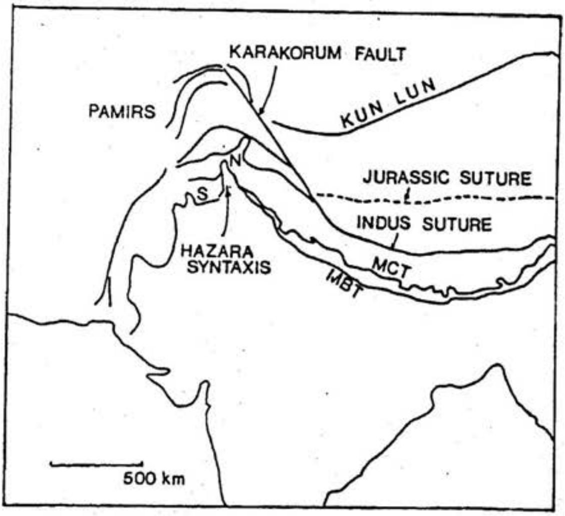


**Fig. 3. Regional map showing the positions of the syntaxis and Karakorum fault in the western Himalaya, Tibet. Pamirs system.**

There is evidence of recent southwest directed thrust movements in the region to the east of Chilas. Here the gneisses have been thrust over Indus river gravels, smashing the gneissic texture and forming a low-gade cataclastic fault gouge. West of Chilas there are cataclasites and pseudotachylite bearing fractures.

The region suffers considerable seismic activity and first motion studies on recently active faults suggests SW overthrusting.

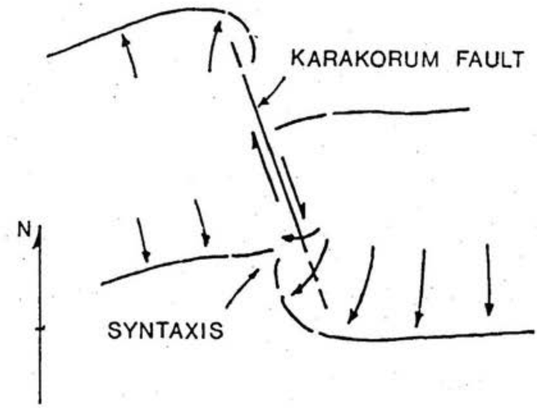


**Fig. 4. Sketch to show the Karakorum fault as a transform controlling arc collision and zones of crustal thickening in the western Himalayas**

This southwest or west directed movement has presumably been active for some time. The large Nanga Parbat $F_3$ fold appears to be large-scale ductile structure folding the gneisses and must have developed on the hanging-wall of some major thrust at depth, or may even buckle the whole upper crust, its wavelength being in the order of 50 km. The muscovite-biotite granites post-date this folding but are themselves slightly warped. K/Ar data obtained by Zeitler (1985) and Rex (in Coward *et al.,* 1986) show young cooling ages, down to about 10 m.y., near the western side of the Nanga Parbat syntaxis, indicating uplift of this part of Kohistan. The cataclastic faults, the uplift of Nanga Parbat over the Indus gravels and the recent seismic activity all attest that this process is still going on.

South of Nanga Parbat, in Hazara, there is another syntaxis where the metamorphic rocks overthrusting the Tertiary Himalayan foreland basin are folded into a large antiformal structure. Further south, in the eastern Salt Ranges, there is interference between the SSE directed foreland thrusts of Pakistan and the SW directed folds and thrusts of the Himalayan arc.

As to what causes the sticking of the Himalayan thrusts and the subsequent development of the arc and syntaxis is problematical. It is possible that the Himalayan thrusts were unable to propagate laterally through the Kohistan complex. There may however be a more fundamental origin. North of the Indus Suture, there occurs the Karakorum fault, which appears as a late structure and makes a pronounced topographic feature. It probably lies along an old transform fault and it separates the India-Tibet collision into two parts. In the west, the Cretaceous Kohistan arc lies trapped between the two plates, while to the east, there is no such arc. Both regions however, show the development of the late Cretaceous to Eocene calc-alkaline batholith. The Karakorum fault also forms the eastern margin to the Pamirs and strongly offsets the zone of crustal thickening from the Pamirs and the Karakorum in the west to the Tibet region in the east. It was presumably active during much of the Himalayan collision and possible earlier; it also forms the western boundary of the Lhasa block which became accreted to the Asian plate during the Jurassic. It is suggested that this fault controlled the position of the Himalayan crustal thickening and acted as the edge of a north Pakistani indentor. It also acted as a lateral ramp to the western Himalayan structures, locally pinning movement so that the thrusts climb laterally to the SW.

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