Structural Tectonics and some Geochronology of Southwestern Nanga Parbat, Pakistan Himalaya

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Abstract

The Main Mantle Thrust (MMT) is the regional contact between collider India and the overthrust Kohistan-Ladakh series in the Pakistan Himalaya. Early Himalayan-age thrusting and some later (~20 Ma?) normal motion on/near the MMT is modified by very young (e.g. 1.4 Ma leucogranite Th-Pb ages) tectonism at Nanga Parbat-Haramosh Massif (NPHM); the Himalaya's western syntaxis. Our investigations in southwestern NPHM reveal a complex interplay of MMT-related (mostly convergent) structural features followed by those related to uplift and tectonism of NPHM. Across the Diamir/Bunar area, main fabrics trend N to NE. In Diamir Valley, Indian cover passive margin metapelites and carbonates in the MMT footwall are not more than a few 100's of metres thick. Here, the regionally NW-dipping Indian cover sequences and MMT hanging wall (Kamila amphibolite) are overturned (SE-dipping). These overturned layers are traceable to the Gashit fold, whose hinge line plunges ~N and axial surface dips gently-moderately east. The cover sequence thickness increases markedly to the south; several km structural thickness of carbonates, metapelites and amphibolites are present in the W-E Airl-Nashkin section, only 8 km to the south of Diamir valley. The cover sequence passes east into a dominantly plutonic 5-10 km thick crystalline sequence where coarse to fine grained granite (the Jalhari granite) grades, due to syn- to post-plutonism deformation, into granitic and porphyroclastic gneiss intercalated with gneissic basement. Regionally the cover and crystalline rocks follow the subvertical to steeply E-ESE dipping foliation, and displacement sense is consistently east side (NPHM) up and over west. Within Diamir valley, granitic and gneissic foliation, shear bands, and local fault gouge zones anastamose around less- to un-deformed Jalhari granite lenses of 10-100's metres width. Plutonism seems to be in part synkinematic, and may provide an older age limit for NPHM tectonism. The E over W sense is consistent with the development of the Gashit fold and the upper limb that includes the overturned cover/MMT layers. The sharp attenuation of the cover sequence in northern Bunar valley could be a result of excision by normal motion along the MMT but we find no compelling evidence for this. We propose that the attenuation is a result of (1) a large frontal ramp in the MMT and an underlying related duplex largely of Indian cover and/or (2) original MMT thrust belt morphology where a lateral ramp-related duplex system has imbricated (and/or infolded) local thin slices of the cover and basement.

Introduction

The Nanga Parbat Haramosh massif (NPHM) has drawn attention for many reasons: (1) the peak of Nanga Parbat (8123m) sits at the NW terminus of the >2500 km Himalayan arc, away from main locus of high peaks, and represents one of the steepest pieces of topography above the sea (Raikhot Valley: 7 km in 21 km; Rupal Face: 5 km in 2 km); (2) NPHM represents an area of exceedingly young plutonism, metamorphism and cooling (Zeitler, 1985; and, e.g. 1.4 Ma Th-Pb monazite age of Mazeno Pass pluton; Schneider et al., 1997), that occurs within Indian plate crystalline rock that is reworked ~1.8 Ga crust (e.g., Zeitler et al., 1989; Chamberlain et al., 1989; Smith et al., 1992) - a crustal protolith apparently lacking from the main High Himalaya; (3) NPHM has been exhumed from several 10's of km beneath the Kohistan-Ladakh fossil island arc that is trapped between India & Asia in this part of the orogen (Fig. 1); and (4) these young events require exhumation of 5-10 mm/yr (e.g. Craw et al., 1994). In previous reports (e.g. Edwards et al., 1996 - poster at Fall AGU) we have looked at the central and eastern and southern portions of the massif (Fig. 2). Despite the very high rates of exhumation for NPHM, our detailed mapping has revealed no major normal-motion low-angle detachment structure that would allow several kilometres of crustal section to have been completely removed from the NPHM (Upper-Middle Indus River) drainage area. We have, however found some late brittle normal faults that would assist the erosional unroofing (see the companion poster by Seeber et al., displaying data from the Seismic Experiment that is highly consistent with these field observations). We have shown evidence for major shear zones within the massif that have allowed "pop-up" of NPHM as a result of WNW convergence of this part of the Upper Himalaya. For example, the Rupal-Chichi shear zone is an ~ESE-vergent reverse fault, antithetic to the Raikhot fault on the NW side of the massif. In this poster we present some of our data from SW NPHM, showing evidence for the southward continuation of the mechanical system of the Raikhot Fault. It continues as a diffuse, N-S trending, ~W-vergent, reverse shear zone that is dominated by a belt of sheared granite/gneiss whose ages (3-12 Ma) are slightly older than those in the very heart of the massif. We attempt to separate early India-Asia collision structures (e.g. the Main Mantle Thrust - MMT) from NPHM pop-up structures, and we discuss possible models for the initial morphology of the MMT.

Fig 1.

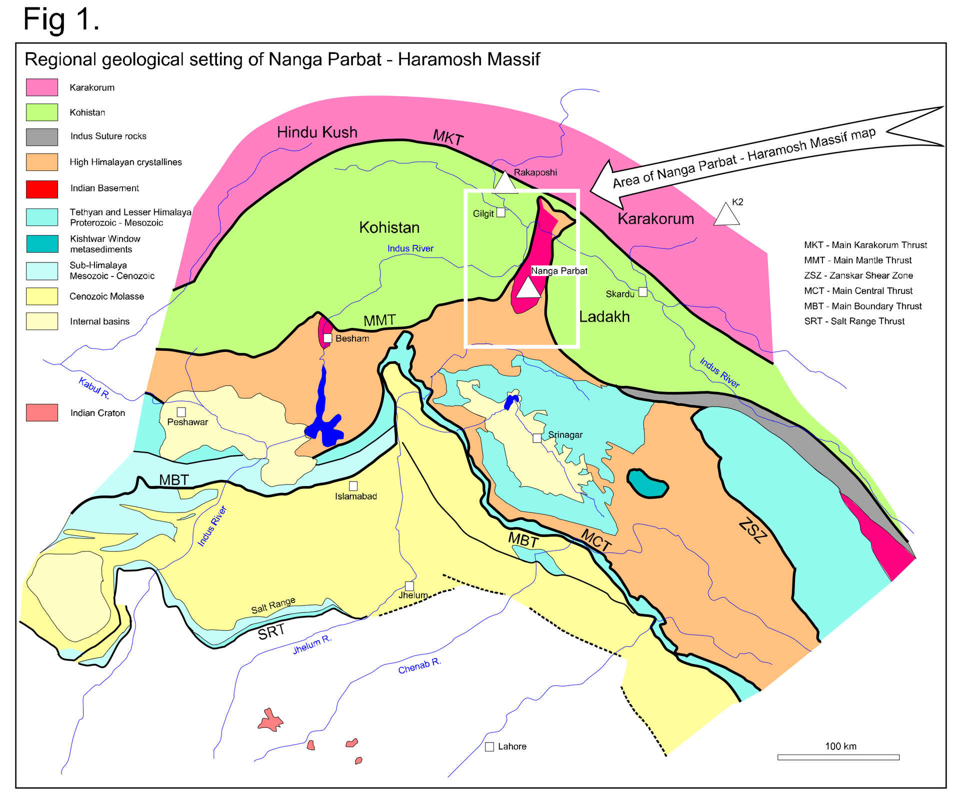
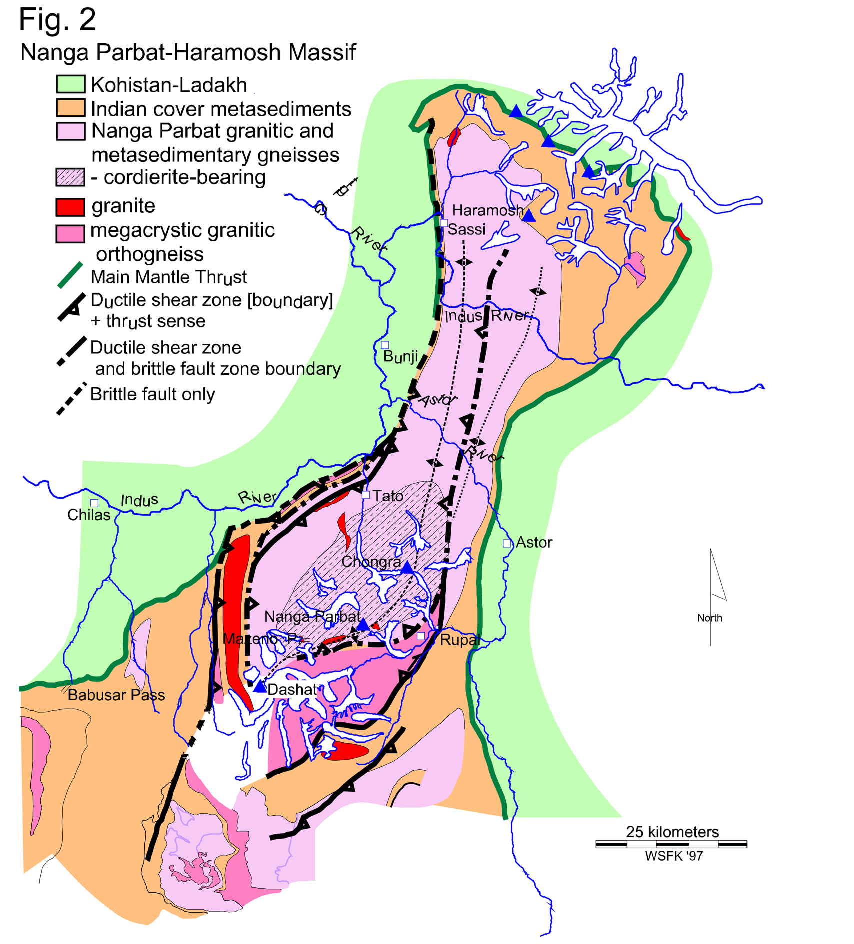


Fig. 2
Nanga Parbat-Haramosh Massif



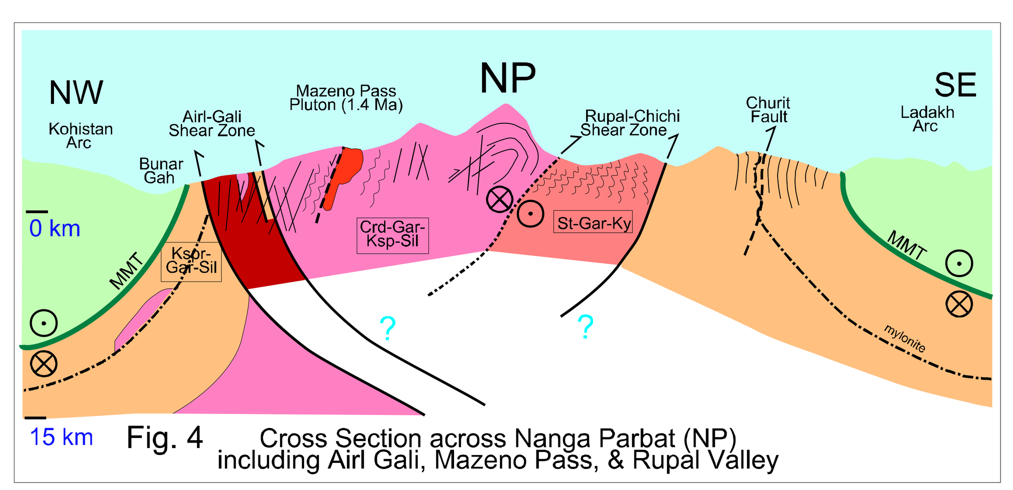


Fig. 4 Cross Section across Nanga Parbat (NP) including Airl Gali, Mazeno Pass, & Rupal Valley

Geology of the southwestern margin of the Nanga Parbat Massif

Indian Cover Sequence

In the area that is encompassed by the N-S trending Bunar valley, and NW trending Diamir valley, the main fabrics trend N to NNE (Fig. 2a). In this area, the Indian cover passive margin rocks that form the original MMT footwall include sequences of carbonates and amphibolites (Permian "Panjal Traps") interlayered with metapelites. In Diamir Valley, these are not more than a few 100's metres thick. Here, the regionally NW-dipping cover sequences and MMT hanging wall (Kamila amphibolite) are overturned (SE-dipping). These overturned layers are traceable to a recumbent open fold (the Gashit fold) in Airl Gah near the village of Gashit, where they form the upper (overturned) limb (Fig. 3). The hinge line and axial plane of the fold plunge gently N. South of this fold, the lower limb dominates the present erosion level, and sequences are not overturned and dip moderately to steeply west. The thickness of the cover sequence increases markedly to the south; carbonates, amphibolites and metapelites of at least 5 km structural thickness are present in the W-E Airl-Nashkin section, 8 km to the south of Diamir valley. This abrupt change in cover sequence thickness is too large to be original depositional variation. Possible tectonic interpretations are given in the discussion.

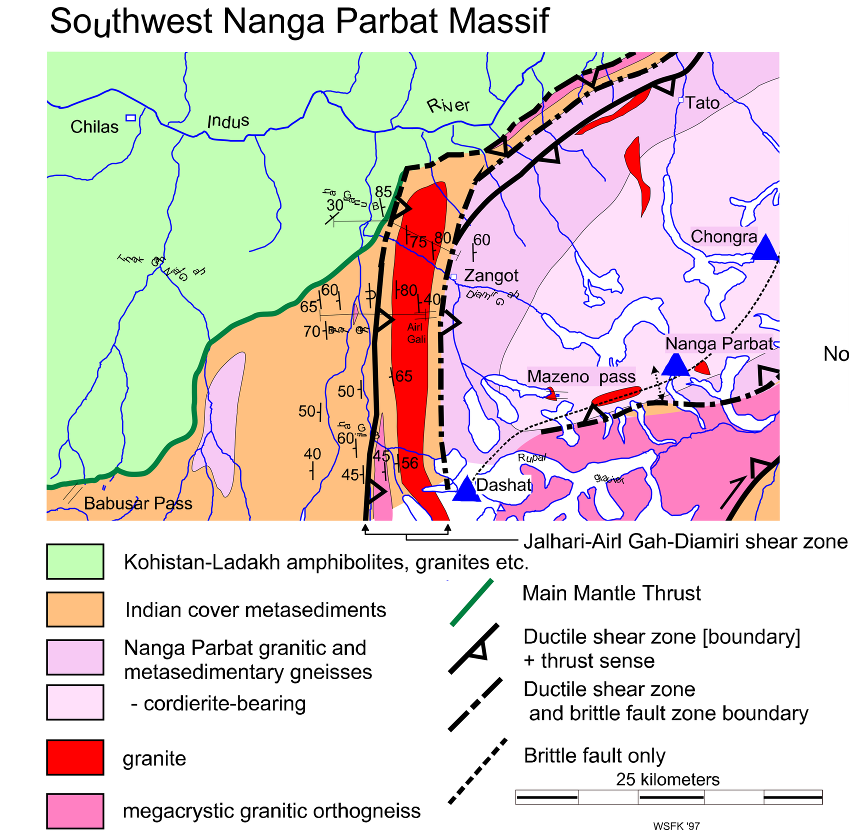
Diamir - Airl Gah - Jalhari Shear Zone

Structurally lower in the MMT footwall, and to the east (Fig. 2a, Fig. 3), the cover sequence passes into a dominantly plutonic, 5 km thick crystalline sequence that forms a continuous ~N-S belt, that is vertical to steeply E-dipping. The Diamir and Airl Gah valleys offer sections through the belt with almost continuous outcrop. From these valleys, it is clear that coarse to fine grained biotite granite (the Jalhari granite) grades into granitic and porphyroclastic gneiss due to syn- to post-plutonism deformation. This is recognised by the relationship between the levels of deformation in the granite-gneiss. Jalhari leucogranite lenses (10s - 100s m thick) show little to no sub-solidus deformation. These lenses are separated by 10s - 100s m thick layers of gneiss where deformation of the granite has been localised. These higher strain layers are anastamosed around the granite lenses, and define reverse faults that climb to the west. The granitic gneiss shows dominantly sub-solidus strain, including S-C porphyroclastic fabric whose sense of shear consistently indicates east side (NPHM) up and over west. Well-developed shear bands, and narrow fault gouge horizons are also found. These are steeply E-dipping and parallel to sub-parallel with the gneissic layers. Late strain is often indicated by narrow (metres) zones where hydrothermal flux has developed thick biotite accumulations. Asymmetric folding (cm-wavelength) of the biotite foliation also indicates east side up and over west. Farther south in Biji Gah, near Garol, leucogranite layers within metasedimentary mylonites near the western margin of this shear zone are spectacularly and syn-kinematically deformed, and deformed veins in the metapelites also demonstrate east-side-up shear sense. Overall the granite gneiss belt defines a steep N-S trending, W-vergent, reverse sense shear zone 5 km in width. The E over W sense is consistent with the development of the Gashit fold and the upper limb that includes the overturned cover/MMT layers. This shear zone forms the mechanical continuation of the Raikhot Fault (a NW-vergent reverse fault with NPHM in the hanging wall). The Raikhot Fault is much narrower (<<5 km) however, and represents more focused strain. We interpret the emplacement of the Jalhari granite to be at least partly syn-kinematic.

Some Geochronology

Th-Pb ion microprobe measurements on monazite grains separated from low-strain portions of the Jalhari granite in the Diamir Valley gave ages of 3-9 Ma. Monazite grains from similarly unstrained portions of a leucogranite, which we think is related to the Jalhari granite, at Garol (20 km to the south of Diamiri) give a Th-Pb age of 12 Ma. Based upon the textural equilibrium of the granites, and based upon monazite saturation temperatures of High Himalayan leucogranites (e.g. Montel, 1993; Harrison et al., 1995), we interpret these as crystallisation ages. Some might interpret these as metamorphic monazite ages, but there is no evidence that the surrounding rocks in the Diamir/Airl region ever attained granulite facies.

Fig. 2a
Southwest Nanga Parbat Massif



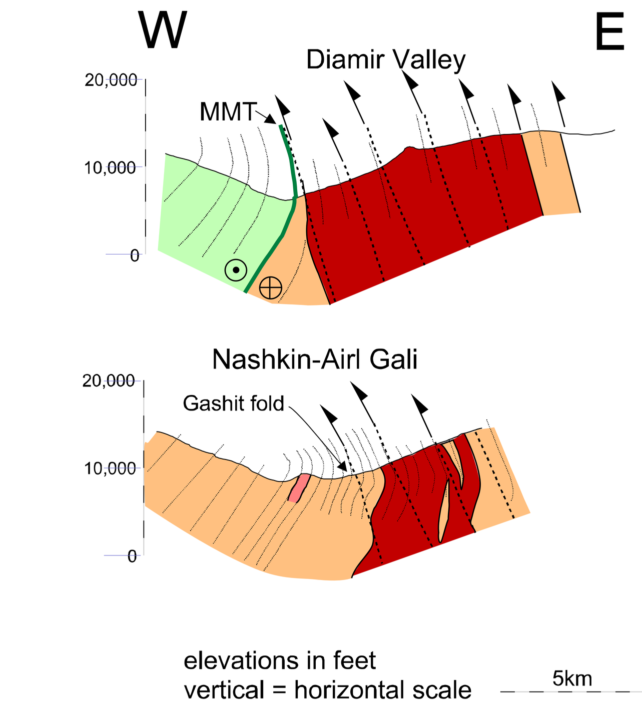
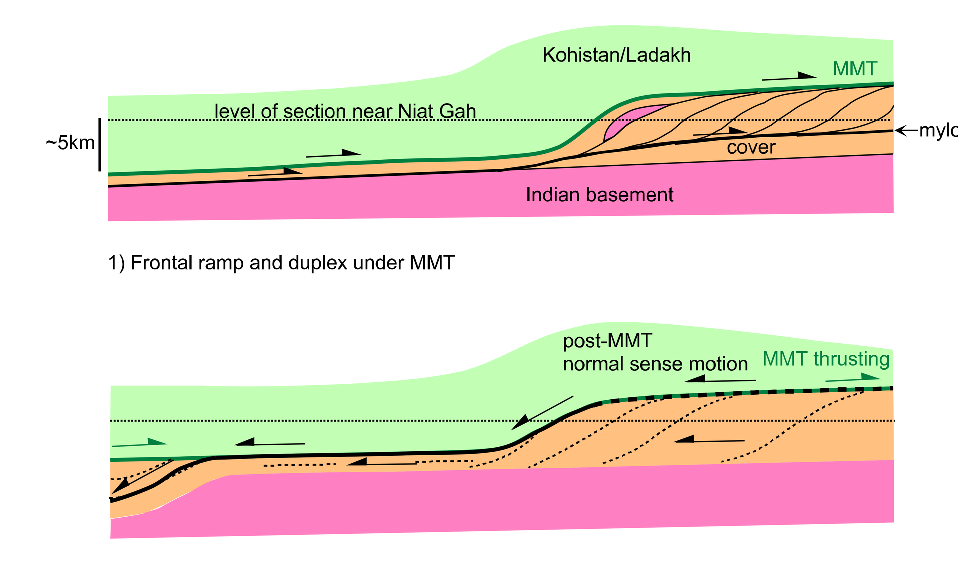


Fig 3 - Cross sections of the southwestern margin of the Nanga Parbat structure

Fig. 5 Cartoon structure sections prior to Nanga Parbat massif uplift and exhumation



Discussion and Interpretation

The mapping of the Diamir-Airl Gah-Jalhari Shear Zone as the continuation along the western and southwestern margin of the NPHM of the Raikot Fault can be integrated with our previous results to show the overall structure of the Nanga Parbat part of the NPHM. This data, summarised on our map (Fig 2)and section (Fig 4) strengthens our previous conclusion that the large-scale structure is that of an antiformal "pop-up" related to displacement on the major discontinuity of the Raikot-Liachar Fault, with secondary but significant antithetic movement on the Rupal-Chichi Shear zone, perhaps generated by a large-scale ramp in the subsurface on the extension of the Raikot Fault. The thermal [cooling age], metamorphic, and plutonic anomalies of the Nanga Parbat part of the NPHM are all contained within the outer boundaries of these two shear zones. The abrupt northward thinning of cover sequences in Southwest NPHM is substantially too large to be original depositional variation and there must be some type of tectonic excision. Large amounts of STDS-type normal motion have not been reported from the MMT - only collapse folding (Burg et al., 1996) or diffuse shear type deformation within the footwall (Vince & Treloar, 1996). Similarly, we have found no compelling evidence for MMT normal motion and, accordingly, we look elsewhere to explain the observed excision. One interpretation is that an east over west reverse fault, sub-parallel with the Jalhari granite-gneiss shear zone, cut out the missing section, but this does not explain the similar relationship on the southeastern side of the NP massif. Such a fault would have to post-date the overturning of the MMT footwall sequences in the Gashit fold. Additionally it would have to be obscured by early plutonism related to the Jalhari granite. Figure 5 shows our more favoured interpretation, as well as a less-plausible alternative. A frontal ramp in the original MMT is suggested to have created a large-scale duplex structure with imbricated slices of cover (and locally basement). This is consistent with our mapping in Niat Gah, the next main N-S valley to the west, where map pattern basement / cover relationships suggest large-scale imbrication below the MMT.

Our interpretation of crystallisation of the Jalahari granite between 3 & 9 Ma in the Diamir Valley, and as old as 12 Ma at Phailobat indicates that there were pulses of plutonism throughout this late Miocene interval. We have reported elsewhere the younger plutonism in the heart of the massif; the Mazeno Pass Pluton is >15 km from Diamir and has a Th-Pb monazite age of 1.4 Ma (Schneider et al., 1997), the Tato Pluton is >20 km from Diamir and has a U-Pb zircon rim age of ~1.0 Ma (Zeitler et al., 1993). Viewed together these ages indicate that plutonism at NPHM has continued since 12 Ma. Other workers (e.g., Wheeler et al., 1995) have emphasised the importance of crustal fertility (crustal melt-production capability) with respect to plutonism at Nanga Parbat and have suggested that basement at NPHM may not have melted twice. Our results show that discrete pockets of melt can be generated at any time, and there is no evidence of a single, widespread melting event. Recognising the relationship between local plutonism and large shear zones (c.f. Mazeno Pass Pluton), we infer that melt can be locally generated when suitable conditions of pressure, temperature, strain localisation, and nature of protolith and/or presence of fluids are attained. We note that the amounts of melt are small when compared to the High Himalayan leucogranites where single widespread melting events are thought to have occurred (e.g. Harrison et al., 1997). Our results indicate that tectonic evolution of Nanga Parbat is a dynamic and ongoing process, of which we have a present-day snapshot.

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This poster is dedicated to the memory of Aslam Mohummad, our great friend and logistics-wizard in Pakistan. He died suddenly and unexpectedly in September 1997.

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