Journal of Nepal Geological Society, 1995, Kathmandu, Vol. 11, Special Issue, pp. 63-72

Where is (Is there a?) Main Central Thrust in the NW Himalayas of Pakistan?

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ABSTRACT

The term "Main Central Thrust" was first introduced into Himalayan terminology in 1939. Still today, much discussion exists about whether the Main Central Thrust is actually one, two or three thrust surfaces, especially in the Central Himalaya of India and Nepal. As the Main Central Thrust is widely accepted as the intracontinental thrust that separates the Higher and Lesser Himalaya, its recognition is therefore implicit in using these unit names in the Pakistan Himalaya. The location of any "Main Central Thrust" in the Pakistan area of the Northwest Himalayan region is likely to remain controversial for some time. This is simply because the area where the Main Central Thrust was last seen, to the south of the Kashmir Basin, was some 100 km away from the next suggested location in Neelum and Kaghan Valleys. This intervening area between the last known location and any new suggested location is only scantily mapped in part. Eleven suggestions of locations of the "Main Central Thrust" have been made in Pakistan and a review of their indicative features is given for discussion. Only one position of the Main Central Thrust, at Batal in the Kaghan Valley, is generally accepted by the majority of northwest Himalayan workers (who do believe in a continuation of the MCT) as the correct location for a major tectonic contact which might correlate with the Main Central Thrust.

INTRODUCTION

The recognition of the Higher Himalaya in the Northwest Himalayan region is a matter of controversy. It therefore seems appropriate to review what is implied with the term "Higher Himalaya", what it defines, and how acceptable the boundary conditions are for the use of the term. In essence, three factors need to be considered for the use of the term "Higher Himalaya". Firstly, a shear zone at the base of the Higher Himalayan Unit that corresponds to the definition of the Main Central Thrust. Secondly, a Himalayan-aged ductile deformed, high grade metamorphic unit containing rocks of granites and gneisses of Cambrian age or older, that are subsequently emplaced to the surface by Himalayan exhumation processes. Finally, a northern boundary that shows a marked variation in tectonic style, metamorphism and deformation from the underlying deformed tectonic unit and the overlying unit. It must have played an essential role in the uplift and erosion of the Higher Himalaya due to the nature of the underlying boundary conditions. The Higher Himalaya is, therefore, a fault-bound unit that has been subducted to great depths, generally in the order of some 30 - 40 km, and was subsequently uplifted and eroded to the surface. There are only two methods by which this can be achieved: erosion and extension. If erosion is the main exhumation process, then it has to be rapid enough to override the subduction-related processes of the Indian Plate underthrusting. If extension is the main exhumation process, a suitable structure needs to be located which shows that the Higher Himalaya were exhumed beneath it. With these considerations in mind, the boundary conditions of the suggested Higher Himalaya in the NW Himalaya need to be reviewed to see whether they fulfil the necessary requirements for the upper and lower definitions for the Higher Himalaya. One of the most controversial of these boundary conditions is the shear zone at the base of the Higher Himalayan Unit that corresponds to the definition of the Main Central Thrust.

THE MAIN CENTRAL THRUST

The term "Main Central Thrust" was first proposed by Heim and Gansser (1939). They described it as a tectonic contact surface between the terrigenous - carbonate autochthon and the overlying metamorphic complex of mica schists and gneisses. The thrust zone always dips to the north at angles of some 15° - 45°. Much confusion about whether the Main Central Thrust is actually one or two thrust surfaces has been

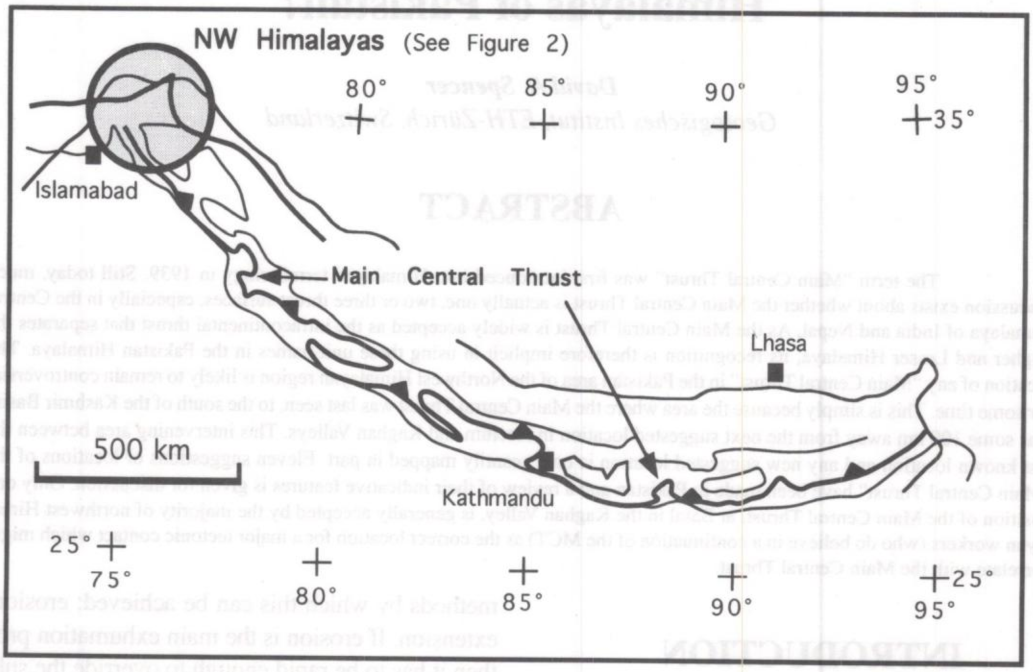

Fig.1 Map of the Himalayas showing the known extent of the Main Central Thrust (map redrawn from Pêcher, 1991). The location of the Main Central Thrust can be traced along most of the length of the Himalayan region up to the NW Himalayas

especially common in the Central Himalaya (Sinha, 1989). For example, Pati and Rao (1981) suggested that the Chail Thrust surface is the base of the Main Central Thrust whilst the Jutogh Thrust is the roof. At places where both thrusts are present, the lower Chail Thrust has been called the Main Central Thrust, whereas where the Jutogh Thrust comes into contact with the sedimentary rocks, it is also called the Main Central Thrust. Valdiya (1980), whilst redefining the Main Central Thrust, subsequently proposed another thrust further to the north and called it the "Vaikrita Thrust". Shackleton (1981) studied the Main Central Thrust in Tibet and Nepal and suggested it to be the limit of the Higher and Lesser Himalaya. He noticed that instead of a single metamorphic break, there is a steep metamorphic gradient, implying that the Main Central Thrust must at least be partly pre-metamorphic and a shear zone rather than a single thrust. The location of any Main Central Thrust in the Pakistan area of the Northwest Himalayan region is controversial (Fig. 1). The Main Central Thrust was last mapped to the south of the Kashmir Basin in India (see Searle et al., 1988) and is some 100 km away from the next suggested location in Neelum and Kaghan Valleys of Pakistan. This intervening area between the last known location and any new suggested location has been only scantily mapped in part. This is due to a border dispute between the countries of Pakistan and India regarding the Kashmir region. Therefore, correlations are made without reference to recent mapping in the region, although some old maps (e.g., Wadia, 1931) are useful.

THE MAIN CENTRAL THRUST - A DEFINITION

The Main Central Thrust is widely accepted as the intracontinental thrust that separates the Higher and Lesser Himalaya (Pêcher, 1977; Brunel, 1986), along which continental crust has been thrust up and thickened. It generally dips towards the north and is not a single tectonic discontinuity, but rather a thick shear zone, in places reaching up to 20 km, but usually about 5 km. It is associated with a strong stretching lineation (Brunel, 1986) and a strong foliation. Around the Makalu - Everest region, the minimum overriding distance is about 100 km (Brunel, 1986). Problems with the recognition of the Main Central Thrust are due to the fact that it was defined on lithological or metamorphic conditions, rather than structural features (such as deformation intensity or strain). The Main Central Thrust should be regarded as a zone of high strain, usually about 5 km thick, along which the mylonites show evidence of large displacement. It is clear, however, that whilst the structural definition of the Main Central Thrust can be made, its implications for metamorphic, stratigraphic, and tectonic considerations are particularly important. For any location of the Main Central Thrust to be accepted, it must comply with most, if not all, of the above definition. Therefore, a description or location of a possible Main Central Thrust can not be considered without comparing on a regional scale what the implications of this definition mean. With this in mind, the first location of the Main Central Thrust at Batal, Kaghan Valley, as described by Chaudhry and Ghazanfar (1986, 1990), is as yet the only location of the Main Central Thrust in Pakistan that seems to fulfil all of the necessary requirements.

LOCATIONS OF THE MAIN CENTRAL THRUST IN THE NW HIMALAYA

There are many suggestions that have been made for the location of the Main Central Thrust in the Northwest Himalayan region (Fig. 2). The aim of this paper is simply to review observations made by various workers and to evaluate the evidence given for described locations of the Main Central Thrust in Pakistan. It is obvious that not all of these interpretations can be correct, although it is worth summarising these locations with their indicative features. Eleven "Main Central Thrusts" have been located in the Northwest Himalaya.

1. A MAIN CENTRAL THRUST ON THE WESTERN SIDE OF THE NANGA PARBAT SYNTAXIS

Coward et al. (1986) and Madin et al. (1989) have suggested that the western edge of the Nanga Parbat Syntaxis (the Raikot Fault) is a terminal tear fault of the Main Central Thrust (Fig. 2 - thrust indicated as 1). Their evidence is based on the regional geology of the Nanga Parbat syntaxis which is suggested to be associated with the rotational underthrusting of the Indian continental crust. They argue that the Main Central Thrust, which is dipping to the northeast in the Central Himalayas, becomes a southeast (eventually south - north) strike-slip fault where the Main Central Thrust encounters the western edge of the Indian Plate slab. This subsequently causes east - west compression against the Asian Plate material to the west. Madin et al. (1989) give supportive evidence for these ideas. Primarily, they argue that the Nanga Parbat Massif incorporates a Higher Himalayan Crystalline Basement "high" that effectively resulted from crustal thickening. This crustal thickening was achieved by a ramp structure in the Indian basement. This implies that the Higher Himalaya terminates at Nanga Parbat and, therefore, the Main Central Thrust must underlie the Nanga Parbat Syntaxis. Moreover, as no Indian Plate basement rocks are known to the west of the Nanga Parbat Syntaxis, it suggests that this location now approximately marks the edge of the pre-collision Indian craton. Finally, recent movements on the Raikot Fault match the development of the Main Central Thrust and associated crustal ramps, but not the initial collision deformation between India and Asia.

With this evidence, Madin et al. (1989) further go on to point out that they have not mapped a connection between the Raikot Fault and any of the known Main Central Thrusts from Kashmir and India. It is, therefore, useful to note their observations that the western margin of the Nanga Parbat Syntaxis is the terminal tear fault of the Higher Himalaya. Crustal ramping, as described by Madin et al. (1989; see Fig. 10), shows that the ramp must have initiated at least in depths of 30 to 35 km to "uplift" the amphibolite facies rocks of the Nanga Parbat Syntaxis. Ramp-flat geometry (or thin skinned tecton-

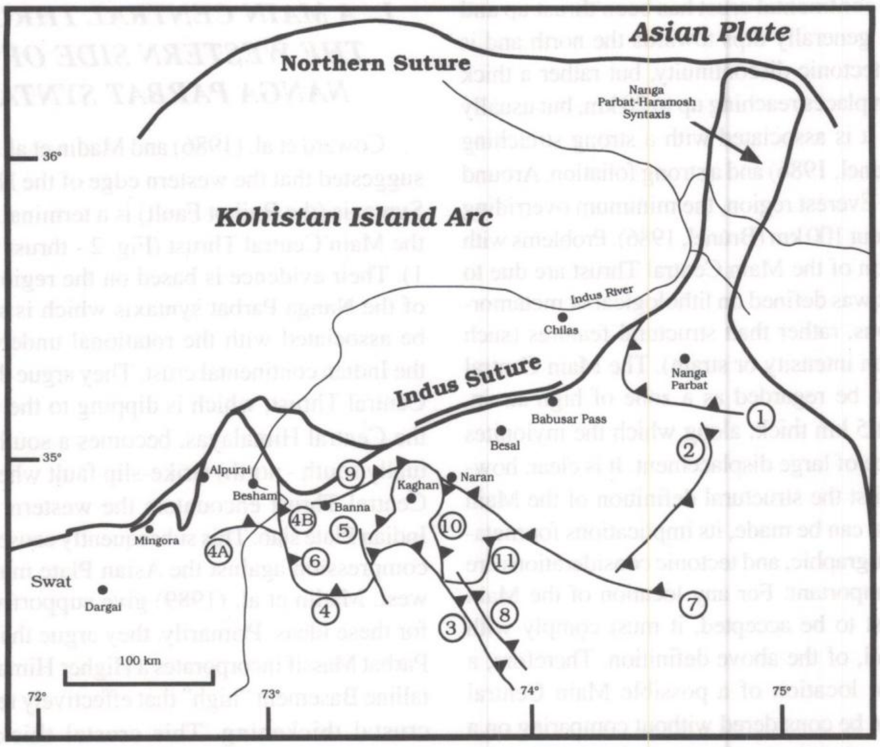

Fig. 2 Map of the Northwest Himalaya to show suggested locations of the Main Central Thrust (see text for location of numbers)

ics) is suggested to be only appropriate for the external frontal portions of mountain belts (see Ramsay, 1988 for discussion). Making crustal ramps to such depths would not only be mechanically unwise but is incompatible with structural observations. The Nanga Parbat Syntaxis is an antiformal structure, possibly two antiformal structures (see Treloar et al., 1991), that have a rounded hinge. These folds are not the kink-like folds that would be related to ramp-flat geometry. Moreover, these highly strained rocks have strain values completely outside those predicted for the formation of folds related to ramping, when conditions of ductile deformation are prevalent. Noticeably, the Raikot Fault (or its suggested recent terminology, the Liachar Thrust (Butler and Prior, 1988)) have only been found along the length of the western side of the syntaxis along strike for some 25 km, around the Raikot area. If the "uplift" of the Higher Himalayan slab was achieved by the crustal ramping method described above, all the present estimations of the Raikot Fault are indeed modest to explain such a large amount of movement.

The suggestion that the Higher Himalaya terminates at Nanga Parbat is disputable. In Upper Kaghan, Chaudhry and Ghazanfar (1987), Hubbard and Spencer (1990), Pognante and Spencer (1991), Spencer et al. (1990, 1991), Greco and Spencer (1993), Tonarini et al. (1993) and Spencer (1993) have concluded that the amphibolite to eclogite facies rocks of the Upper Kaghan region are those of the Higher Himalaya Crystalline, last known in the Zanskar region. The Higher Himalaya does not terminate at Nanga Parbat but can be correlated further west into the Swat region, albeit with far less certainty. Moreover, recent work by Treloar et al. (1989) and Baig (1991) in the Besham area has established that crystalline granites of the 1,800 Ma event are located in the Besham Syntaxis which have subsequently been correlated to the Indian Plate Basement. Finally, do the recent movements on the Raikot Fault match the development of the Main Central Thrust and associated crustal ramps, but not the initial collision deformation between India and Asia? Treloar et al. (1991)

note that the stretching lineations in the Nanga Parbat region are essentially north - south. The stretching lineations are usually attributed to the nappe forming movements associated with the development of the Higher Himalaya (see Brunel, 1986) and presumably with the collision at that time of the Indian Plate with the Asian / Kohistan Island Arc. The basal thrust of the Higher Himalaya Crystalline has always been regarded as the Main Central Thrust, therefore, the stretching lineations recorded by Treloar et al. (1991) should at least be correlated with the movements of the Main Central Thrust. Madin et al. (1989) now argue that the east - west compressive movements along the Raikot Fault are those of the Main Central Thrust. This would imply that the initial movement direction of the Main Central Thrust was north to south and that now it displaces similar rocks of the same age by east to west movements. They therefore suggest that it is the same structure producing both sets of movements in opposite directions at the same time, yet producing different structures associated with it. Clearly, there is some timing problems associated with this scenario.

Finally, by definition, the Main Central Thrust separates the Higher Himalaya from the Lesser Himalaya. The recent finding of eclogite facies rocks in the Upper Kaghan would have appear in the Lesser Himalayan tectonic setting of the northwest Himalayas according to Madin et al. (1989). Again, problems exist with these tectonic subdivisions, as Lesser Himalayan rocks along the whole length of the Himalayas rarely are above greenschist facies. If the terminal tear fault (Main Central Thrust) is accepted, then an eclogite facies Lesser Himalaya would clearly contradict Lesser Himalayan definitions.

2. THE SHONTARGALI THRUST IS AN ANALOGUE OF THE MAIN CENTRAL THRUST

Tahirkheli (1987, 1988, 1989, 1992) suggested that the Shontargali Thrust is an analogue of the Main Central Thrust (Fig. 2 - thrust indicated as 2). Its southern extent is located in the Barai stream of Neelum Valley where it continues north - northeast over the Shontargali Pass and enters the Astor valley following the Mir Malik stream before swinging north - northwest to merge along the western edge of the Nanga Parbat Syntaxis (roughly parallel to the Raikot Fault). Evidence for the Shontargali Thrust being an analogue of the Main Central Thrust is based on stratigraphic, structural and metamorphic evidence. Tahirkheli (1987, 1988, 1989, 1992) shows that the Salkhala Series (regarded to be of Precambrian age) is thrust to the south - southwest over the Nanga Parbat gneisses (regarded to be 1,800 - 2,700 Ma). The cross section (Fig. 3) shows this sense of thrusting quite clearly towards the south - southwest even though the thrust itself strikes south - southwest to north - northeast. Moreover, the ornament on the Main Central Thrust, following conventional practice, indicates that the sense of movement of the thrust is to the northwest. This would effectively bury the Nanga Parbat Massif rather than uplift it, which would be expected for the Main Central Thrust movements. However, just to the south - southwest of the Main Central Thrust in Kel Nala, Nanga Parbat Gneisses are exposed again, suggesting that the Main Central Thrust should also pass again between this lithological unit. The southeastward dipping Main Central Thrust would, therefore, have to turn and strike from southeast to northwest to solve the accommodation of the uplift of the Nanga Parbat problem.

Tahirkheli (1987, 1988, 1989, 1992) describes the Salkhala Unit as middle greenschist facies, although locally elevated to kyanite and sillimanite grade. The Nanga Parbat gneisses are described as being deformed by ductile deformation, suggesting metamorphic grades of at least amphibolite facies. From these observations, it does not seem that the Shontargali Thrust is separating any large metamorphic break. Again considering the problems of putting the eclogite facies rocks of the Upper Kaghan valley into this tectonic scenario, the strike of the Shontargali Thrust would have to change from northeast - southwest to northwest - southeast. This would effectively make the thrust three sides of a domal structure which indeed would question its evolution as one of the Himalayan tectonic scars. The only possible alternative is that the Shontargali Thrust could be a tectonic window, analogous with those seen in the Kitswar area of India. However, the detailed stratigraphic studies in the Upper Kaghan area suggest that the Shontargali Thrust is not even a thrust, but mapped as perhaps the contact of the basement

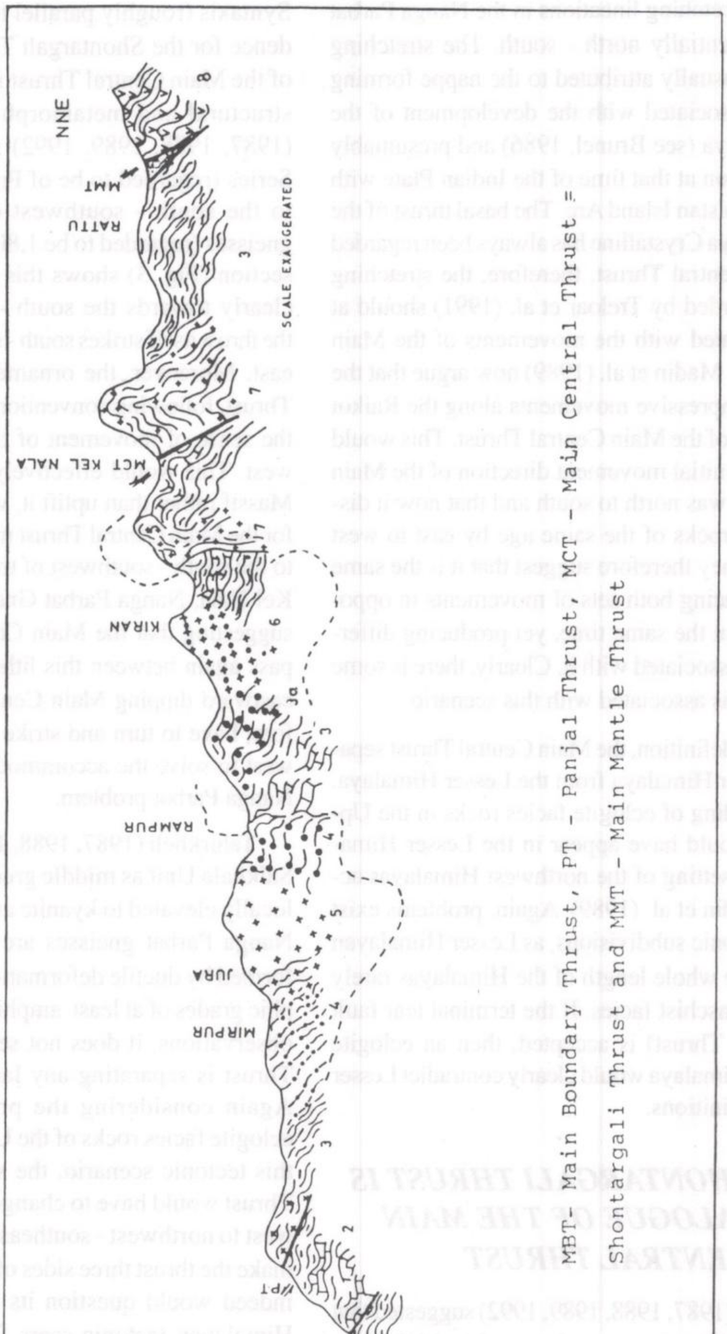

Fig.3 Cross section along Nilam (Neelum) Valley to show the position of the Shontargali Thrust (Main Central Thrust) (taken from Tahirkheli, 1992)

units of the Higher Himalaya and its overlying cover. Further fieldwork in this extremely interesting region is needed to solve this dilemma.

3. THE PANJAL FAULT IS, IN PART, THE EQUIVALENT OF THE MAIN CENTRAL THRUST

The last known location of the Main Central Thrust is to the south of the Kashmir basin (Honegger et al., 1982; Frank et al., 1977; Searle, 1991) where it is overlying the Panjal Thrust. As both strike towards the northwest, the surface expression of the Main Central Thrust is subsequently not very clear. It has therefore been suggested, due to the fact that no further location of the Main Central Thrust in the northwest Himalayan region has been found, that the Panjal Thrust in part acts as the equivalent of the Main Central Thrust (Gansser, 1964). The deformation is, therefore, transferred from the Main Central Thrust to the Panjal Thrust and the Main Central Thrust supposedly dies out (Fig. 2 - thrust indicated as 3). This idea was taken on by various authors (Calkins et al., 1975; Lawrence et al., 1988; Seeber et al., 1981) who extended the Panjal Thrust west around the Hazara-Kashmir syntaxis, so indicating that it was possibly an extension of the Main Central Thrust.

4. THE MANSHERA AND PANJAL THRUSTS ARE COEVAL TO THE MAIN CENTRAL THRUST

Coward et al. (1988) designated that the internal and external units of the Indian Plate were separated by the Manshera and Panjal Thrusts (Fig. 2 - thrust indicated as 4). They, therefore, suggest that these thrusts were the equivalent of, but not necessarily coeval to, the Main Central Thrust of the Eastern Himalayas. They note that the southern thrust sheets near Manshera carried a granite dated at 500 Ma (Le Fort et al., 1980) intruded into already metamorphosed sediments. The location of the Main Central Thrust, according to this interpretation, is somewhat confusing. Fig. 2 - thrust indicated as 4.A (location taken from Fig. 1 of Coward et al., 1988) shows the Main Central Thrust as the Manshera Thrust that takes a 90° turn across the Indus river, south of Besham before being covered by the Peshawar basin. In contrast, another map by Coward et al. (1988) (Fig. 5a, p. 98) shows the Main Central Thrust striking north - south before being cut by the Indus Suture and no such fault is located as seen in the Fig. 1. (Fig. 2 - thrust indicated as 4.B).

5. THE BALAKOT SHEAR ZONE IS THE EQUIVALENT OF THE MAIN CENTRAL THRUST

Greco et al. (1989) suggests that the Balakot Shear Zone, first recognised by Bossart et al. (1988), forms a very important structural and metamorphic discontinuity separating the underlying Salkhala Unit from the overlying Higher Himalayan Crystallines (Fig. 2 - thrust indicated as 5). Along the western side of the Hazara-Kashmir syntaxis, it changes from a moderately inclined ductile shear zone into a sub-vertical left-lateral strike-slip shear zone, giving rise to strong deformation in the Panjal Unit and also a slight deflection of cleavage in the Sub-Himalayan Murree Formation. The shear deformation is described as being synchronous with, or later than, the northeast - southwest directed thrust structures.

6. THE OGHI THRUST IS THE EQUIVALENT OF THE MAIN CENTRAL THRUST

The Oghi Thrust (Coward et al., 1986) or the Oghi Shear Zone (Treloar et al., 1989) divides the Tanol Unit from the crystalline rocks which, at least in part, is related to southwesterly directed structures. Greco et al. (1989) therefore suggest that the Oghi Shear Zone may be the tectonic equivalent of the Main Central Thrust (Fig. 2 - thrust indicated as 6).

7. THE LUAT FAULT IS THE EQUIVALENT OF THE MAIN CENTRAL THRUST

Chaudhry and Ghazanfar (1986) noted that the Batal Fault in Kaghan Valley could be joined with the Luat Fault in Neelum Valley to demarcate the Main Central Thrust (Fig. 2 - thrust indicated as 7). They based their evidence of stratigraphic, metamorphic and structural observations around the Luat region of the Neelum valley.

8. THE MAIN CENTRAL THRUST IS LOCATED IN THE LOWER PART OF NEELUM VALLEY

Greco (1989) mapped the lower part of Neelum Valley in the Badri Gali - Nauseri area and, in contradiction to Chaudhry and Ghazanfar (1986), located the Main Central Thrust at several places (e.g., at Harla Baikh, north of Galihetar, Musagali Baikh) (Fig. 2 - thrust indicated as 8). This location is also based on structural, stratigraphic and metamorphic evidence.

9. THE MAIN CENTRAL THRUST IS THE NORTHWARD CONTINUATION OF THE BATAL FAULT

Chaudhry and Ghazanfar (1992) extended their Batal Fault (Main Central Thrust) northwestwards to Challayan in Kaghan valley and westwards to Biari before turning northwards and terminating at the Indus suture (Fig. 2 - thrust indicated as 9). Subsequently, it reappears along a strike slip fault to the east of the Indus river and moves westwards across the base of the Besham block to Pacha and Malakand. They, therefore, do not correlate the Main Central Thrust with the Oghi Shear Zone which goes around and south of the Hazara Nappe (Treloar et al., 1989) to Talakot. Subsequently, they argue that the Hazara nappe is more likely to be part of the Lesser Himalaya rather than the Higher Himalaya.

10. THE MAIN CENTRAL THRUST IS FOLDED TO FORM THE KAGHAN SYNTAXIS

Papritz (1989) and Rey (1989), as well as Greco et al. (1989) suggest that the Main Central Thrust is folded to form the Kaghan Syntaxis in the Naran area (Fig. 2 - thrust indicated as 10). Detailed structural mapping showed the presence of a domal structure which deforms the Main Central Thrust into a half-window.

11. THE MAIN CENTRAL THRUST IS BETWEEN BATAL - MUSA GALI - LUAT IN THE NEELUM VALLEY

Fontan and Schouppe (1994) delineate the MCT between the recognised locations of Batal (Ghazanfar and Chaudhry, 1985) and Luat (Chaudhry and Ghazanfar, 1990). However, they locate the MCT to be folded around the Musa Gali area (as delineated by Greco, 1989). The MCT is described as a more than 100 m thick shear zone expressed by dark mylonites in the schists and light schistose mylonites in the granites (Fontan and Schouppe, 1994).They also note that the MCT encloses numerous traces of metasomatism (scheelite-bearing skarns) and that the MCT crosscuts a single stratigraphic sequence, which explains why the Higher Himalaya and Lesser Himalaya show the same stratigraphic features.

DISCUSSION

All the recent geological mapping (e.g., Bossart et al., 1988; Greco et al., 1989; Ghazanfar and Chaudhry, 1985; Chaudhry and Ghazanfar, 1987; Spencer, 1993) of major parts of Neelum Valley and the whole of middle and upper Kaghan Valley has provided for an extension of the Himalayan subdivisions from India and Kashmir into Pakistan by their delimitation of the Main Central thrust, albeit if not all of the locations are exactly agreeing with each other. The delineation of the Higher Himalaya Crystalline and its distinction from the Lesser Himalaya in Pakistan can only be made possible by the delineation of the Main Central Thrust.

Only one position of the Main Central Thrust, at Batal in the Kaghan Valley, is generally accepted by the majority of northwest Himalayan workers as the best location for the Main Central Thrust (Gansser, 1979; Chaudhry and Ghazanfar, 1986; Chaudhry and Ghazanfar, 1990; Greco et al., 1989, Spencer, 1993). All agree that at Batal, the Main Central Thrust separates the Higher Himalayan Crystalline in the north from the Lesser Himalaya to the south. The thrust is a north dipping (45°) ductile shear zone of some 1 km width.However, whether the Main Central Thrust is traced between Luat in Neelum valley through to

Batal, near Naran in Kaghan Valley and finally to Chlalayyan near the Kaghan - Kohistan watershed (Chaudhry and Ghazanfar, 1990), or as suggested by Greco (1989) to the lower part of Neelum Valley in the Badri Gali - Nauseri area, needs to be resolved. This extension of the Main Central Thrust into Pakistan may, at least, facilitate the subdivision of the Northwest Himalaya up to and east of a line passing north - south through the Hazara-Kashmir syntaxis, covering the areas of Neelum and Kaghan.

However, it is clear that there are many problems in recognising in the Northwest Himalaya what the true characteristics of the Main Central Thrust are. It is seemingly impossible to reconcile that all the previously mapped "Main Central Thrusts" are part of one single fault and this may indicate that the thrust is more complex or an incipient fault in the Northwest Himalaya than in the Central Himalaya. Alternatively, the tectono-stratigraphic sub-units of this region could be thrust sheets which are subdivided by an overall series of Main Central Thrust-type structures (e.g., MCT I, II and III) which have been previously described in the Himachal and Kumaun Himalayas (see Thakur, 1992). Finally, it is also important to note that other workers in the NW Himalayas suggest that the terms "Higher- and Lesser Himalaya" be discontinued completely in this region, suggesting that the Kashmir region marks the true terminal extent of the Main Central Thrust.

ACKNOWLEDGEMENTS

DAS was financially supported by the ETH Grant Nr. 0.20.367.89, as well as an ETH-Imperial College Scholarship 0.330.028.02/8. Funding to travel to the 9th Himalayan-Karakoram-Tibet Workshop was provided by a Swiss National Science Foundation Grant No. 2100-039080.93/1. Thanks are due to N. Chaudhry, M. Ghazanfar, J.G. Ramsay and C. Spencer-Cervato. A review from an anonymous reviewer is appreciated.

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