within middle greenschist to amphibolite facies metamorphism. The metapelites consist of muscovite, chlorite, garnet, plagioclase, quartz, chloritoid, staurolite, sillimanite and opaque. Garnet occurs as small porphyroblasts within the main foliation and its inclusion trails suggest syn-tectonic growth. S-C fabric is well developed in mica schist along with numerous mineral fishes. Greenschist /amphibolite contains plagioclase, quartz, actinolite, hornblende, chlorite, epidote, zoisite/clinozoisite and porphyroblastic garnet of variable sizes in the assemblage. Calcite and dolomite marble contain calcite, chlorite, zoisite, talc, tremolite and diopside. A band of augen mylonite has been traced for many kilometers and represent a splay of the main shear zone within the Karakoram Mountains. Metabasite and impure marble dominate over the psammite and pelite of the KMB towards Phobrang. Selected mica schist and amphibolite were probed for equilibrium mineral assemblages for their chemical composition and P-T condition of metamorphism using well-calibrated geothermobarometers. The KMB has been metamorphosed at about 500° C and 6.2 Kb to about 700° C and 8.60 Kb, which are also corroborated from phase equilibria mineral reactions and the assemablges. The KMB zone is characterized by intense penetrative ductile shearing as the most prominent deformation phenomenon, having top-to-SW sense of thrusting and subhorizontal stretching/mineral lineation, as has been deciphered from numerous shear criteria. It is superposed by ductile to brittle normal faults and other structures of extensional tectonics which is associated with the exhumed Karakoram metamorphics within transpressive domain.

Timing and amount of crustal shortening, Shuanghe area, Central Tibet

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Geological work during the INDEPTH III project in the region of the settlement of Shuanghe (88°50E, 33°10N) reveals new information bearing on the timing and amount of crustal shortening in this region of the central Chang Tang terrane of the Tibetan Plateau. Marine strata of Jurassic and older ages are moderately to strongly folded throughout this region and cut in places by thrusts, with N-S shortening amounts up to about 50%. These are locally overlain unconformably by less strongly folded strata, mainly red clastic rocks ranging from conglomerates to shales, with N-S shortening amounts in the range of about 15% where a detailed section was measured (Narmargh section). In one locality, southwest of Shuanghe, fossil-dated late early Cretaceous strata (Tibet RG Brigade, 1986), pebbly conglomerates, argillites, and calcareous arenites, are found between the overlying redbeds and the underlying more strongly-deformed rocks, with angularly unconformable contacts both above and below. These shallow marine Cretaceous strata suggest that normal crustal thickness existed in the area at deposition. The younger red beds resemble in facies and in north-directed paleocurrent orientation those of known Eocene age (Smith and Juntao, 1988) in the Fenghuoshan (north and northeast of this region), and Chinese investigators (Tibet RG Brigade, 1986) correlate them with similar fossil-dated early Tertiary redbed strata of the Lunpola Basin (to the south of this region). These well-lithified redbed strata cannot be Triassic, as shown by Kapp et al (2000). In this region these redbeds map at the base of E-W elongated basins that contain overlying Neogene, only partly-consolidated clastic strata. These basins are interpreted by us as being of intermontane, crustal-shortening origin; Burke and Lucas (1989) first pointed out that similar strata of the Lunpola Basin had undergone late Tertiary shortening. While there is most probably not sufficent total N-S shortening in the Cenozoic strata of this region to account everywhere for all or most of the doubling of crustal thickness, they are affected by a significant, non-trivial amount, and the shortening is nowhere near zero except locally in the youngest (Pliocene and/or younger) strata.

The melange and ophiolitic rocks that form the oldest exposed rocks in this region have been interpreted by Kapp et al (2000) as originally underthrust from the Banggong Suture. While Kapp et. al. are clearly right that a major regional low-angle detachment fault occurs at the top of this suite of rocks, we prefer a hypothesis for the origin of the melange and ophiolites, including the blueschists first identified by Hennig (1915), that it marks the suture zone between two parts of the Chang Tang terrane. This would provide a simple explanation (first proposed by Kidd et al, 1988) for the major contrast in origin of the "basement" rocks of the Chang Tang, as shown by their Carboniferous-Permian facies and fossils, being Gondwanan and glaciogenic in the west (Norin, 1946), but Cathaysian and non-glaciogenic in the east (e.g. Yin et. al., 1988). Geophysical data obtained during the INDEPTH III project may allow discrimination between these two hypotheses for the origin of the melange.

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Structural evolution of the Karakoram Fault, Ladakh, NW India

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The Karakoram Fault is a 1000 km long strike-slip plate-bounding fault along the southwestern margin of Tibet. Previous studies have estimated a maximum of 120-150 km dextral offset of 21-17 Ma two-mica ± garnet leucogranites (Searle et al., 1998). Long-term average slip rates of 8.3 mm/year have been inferred assuming that the fault has remained active until the present. Variation in cooling ages determined from 40Ar/39Ar ages suggests strain partitioning between transpressional and dominant strike-slip phases with exhumation of migmatites and leucogranites occurring in two main phases, the partitioning transitions occurring at about 13 Ma and 8 Ma (Dunlap et al., 1998).
We have carried out recent field studies in the central portion of the fault along the Nubra valley and Darbuk-Tangste-Pangong Lake region in northern Ladakh. Staurolite-grade metamorphic rocks, orthogneisses, migmatites and ~20-17 Ma leucogranites have been exhumed along the Karakoram fault in this area, where the fault cuts deep crustal rocks. Plastically deformed mylonites and brittle faulting were observed at the same structural level, indicating that dominant strike-slip movement has occurred since the last transpressional phase (c.8 to 7 Ma). The inferred strain transition is supported by the variation in lineation dip-slip between mylonitic and brittle fabrics, each fabric representing a transpressional and dominant strike-slip phase respectively.
Local deformation phases during ductile shearing are inferred from overprinting criteria following an initial microstructural survey of mylonites whilst analysis of brittle fabrics indicates sense of movement along the fault. Along the Nubra valley, evidence of pseudotachylyte and ultracataclasite formation suggests a seismically active period during strike-slip in the past, with the lack of recorded seismicity perhaps indicating recent cessation of movement.
Thermobarometry and current U-Pb dating of pre- syn- and post -deformational two-mica ± garnet leucogranites will constrain further the timing of strain partitioning and the long-term slip and exhumation rates.

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River Response to Active Faults in the Tectonically Resurgent Central Sector of the Himalaya

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The oblique convergence of India with mainland Asia is accommodated by the right-lateral desplacement along transverse faults and strike faults/thrusts and is also manifest in the pronounced dextral deflection of antecedent rivers of the central sector of the Himalaya. Almost all thrusts that define the boundaries of lithotectonic terranes are active for much of their extent, but variably. The fault reactivation is expressed in different geomorphic development and drainage response.
Neotectonic movements along the fault zone that caused detachment of the crystalline foundation, now making the Great Himalaya domain, form the Tethyan sedimentary pile is manifest in the upstream ponding of anticedent rivers with resultant formation of huge lakes and in the downstream development of spectacularly deep gorges. The fluvial terraces lining valleys of practically all rivers and streams upstream of the reactivated thrusts that define the synclinal nappe of crystalline rocks, are confined to the inner Lesser Himalaya of autochthonous sedimentary rock. Commonly three and locally six levels of these fluvial terraces in their veriable stretches between the fault-bound terrane, imply as many pulses of Quaternary uplift along the thrust faults within the Lesser Himalaya. Reactivation of faults of the schuppen zone of the Main Boundary Thrust (MBT) is evident from the pronounced dextral swinging of antecedent rivers, the truncation of colluvial cones and fans in the uncommonly wide valleys that follow the fault zone, the occurrence of sagponds and spectacular valley fills upstream of faults that cross the valleys, and the formation of lakes in the tributary streams cut by the faults genetically related to the MBT. Recent movements along the faults that defines the boundary of the Himalaya against the Indo-Gangetic Plain has considerably uplifted, tilted and locally deformed the late Quaternary-to-Early Holocene and historical gravel deposits that fill the depressions within the Siwalik terrane, and caused entrenchment of Siwalik rivers and streams.
The central sector of the Himalaya pressed as it is by the NNE-E trending Aravali orogen of the Indian Shield, is under very strong strain. The accumulated strain is being relaxed in a couple of pockets, by earthquakes of moderate to small magnitude. The intersections of the Main (Basement) Detachment Thrust and one or another of the conjugate pairs

Addenda Abstracts: 16th Himalaya-Karakorum-Tibet Workshop Schloss Seggau (Austria)

Sm-Nd Mineral Ages of Pegmatite Veins and their Host Rocks from Chilas Complex, N. Pakistan

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Two sets (1515- and D2-series) of pegmatite veins and their host rocks consisting of four samples each from Chilas Complex, N. Pakistan are dated using Sm-Nd system. The mineral assemblage of veins is mainly composed of Plag and HBL with minor amounts of epidote. The host rocks consist of Plag, CPX, OPX and HBL. It is observed that Sm-Nd mineral isochrons of coarse-grained pegmatite veins (1.5-2.0 cm grain radii) give older ages than the fine-grained host rocks (0.025-0.1 cm grain radii) in both series of samples. The old ages in veins might be explained in different ways: i) the vein ages, 107 Ma (1515A) and 94 Ma (D2A), show that magmatic age of Chilas Complex could have been more than 107 Ma, which is much older than the previously reported magmatic age of 80 Ma; ii) these ages probably date the time span of granulite-facies metamorphism in Chilas Complex, which coincides with the approximate period of Kohistan-Asia collision (110-90 Ma); iii) or the vein ages are simply the effect of grain size according to the Dodson's formulation of closure temperature as coarser minerals have higher closure temperatures and vice versa, which consequently affects Sm-Nd mineral age. In 1515-series, the contact between vein and host rocks is sharp and regular. The host rocks major minerals have almost similar grain radii of 0.1 cm and their ages (72-69 Ma) are also very similar. In D2-series, the contact is broken and irregular. The host rock mineral ages very from 76 Ma to 60 Ma. Likewise, the grain radii (~0.1 to 0.025 cm) decrease as the distance increases from the vein D2A. This indicates that some fluid activity might have caused such variations. Moreover, the near vein sample D2B has secondary hornblende produced at the expense of plagioclase and pyroxenes. Its modal abundance also decreases away from the vein. It may be concluded that all the host rock ages are the cooling ages after the granulite-facies metamorphism and the difference in these ages within a short distance might be the effect of grain size variation.

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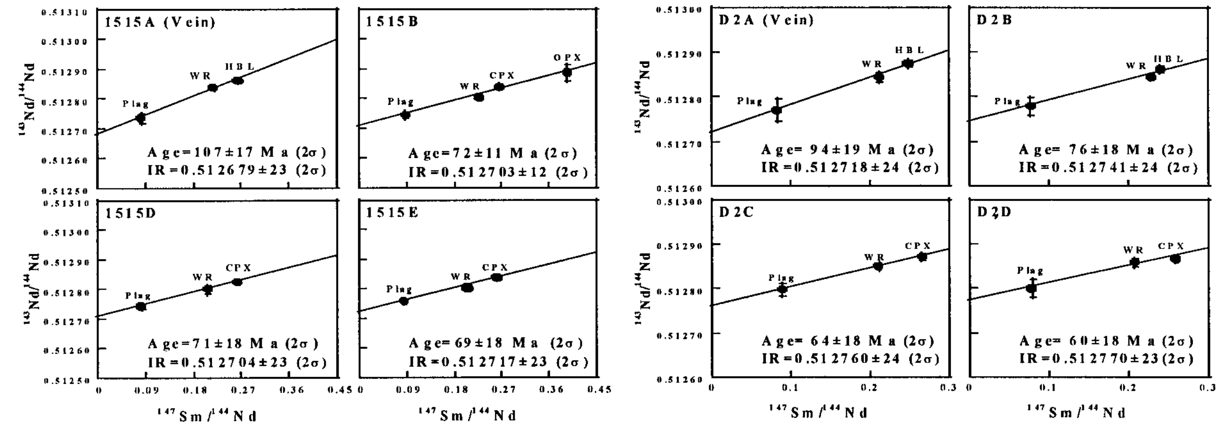
***Figure 1.** Sm-Nd Isochron diagrams of 1515- and D2-series. 1515A-vein (~15cm wide); 1515B-10cm; 1515D-35cm; 1515E-45cm from vein. D2A-vein (~25cm wide); D2B-15cm; D2C-25cm; D2D-60cm from vein. Abb.: Plag, plagioclase; HBL, hornblende; CPX, clinopyroxene; OPX, orthopyroxene; WR, whole rock and IR, initial ratio.*



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