the updoming of the phyllite, and the conditions for quartz veins and new mineral growth are related to the emplacement of a leucogranite (the Karo La granite) that is exposed in several places in the core of the dome. The leucogranite intrudes (cross-cuts) the phyllite, and may provide a minimum age for displacement on the KLD. The Karo La dome is cut by a major graben-bounding N-S normal fault (part of the Yadong-Gulu rift system - YGRS - Wu et al., 1998; Cogan et al., 1998). Li et al. (1998) have determined a crystallization age of 11.7 ± 0.2 Ma (xenotime) for the Karo-la granite. Apatite fission track data from the Karo La granite give an age of 4.7 ± 1Ma, and prior geochronology (Copeland, 1990) gives biotite and muscovite Ar/Ar cooling ages of 10.5 ± 0.1 and 10.9 ±0.1, respectively. These ages imply exhumation of this segment of the YGRS hanging wall between ~10 and 5 Ma, consistent with general opening of the YGRS at this time (e.g. Nyainqentanglha, Harrison et al., 1995, Wu et al., 1998). We have mapped the same phyllite unit in northern Nieru Valley-Kangmar Dome (Kidd et al., 1995), and in another nearby dome (Mangda Kangri), where the phyllite unit in each case is again present defining the core of the dome structure, and with a normal-sense decollement as its upper surface. We suggest that the phyllite marks a regional layer with an extensional decollement, originally N-dipping, that has been since domed in association with granite emplacement (during which the phyllite unit may have acted as some type of barrier to magma ascent). Ages from the main STDS in this segment of the Himalaya (Edwards and Harrison, 1997, Edwards et al., 1995) suggest that it was active at the same time, or perhaps later (the STDS is structurally lower than the KLD decollement). We remark that the existence of this regional decollement within the Tethyan Himalayan belt makes construction of simple balanced sections (e.g., Ratschbacher et al., 1994) problematic in this part of the orogen.

References

Cogan, M.J., K.D. Nelson, W.S.F. Kidd, and C. Wu, 1998. Shallow structure of the Yadong-Gulu rift, southern Tibet, from refraction analysis of Project INDEPTH common midpoint data. *Tectonics*, 17, 46-61.

Copeland, P.C., 1990. Cenozoic Tectonic History of the southern Tibetan Plateau and eastern Himalaya: Evidence from ^{40}Ar/^{39}Ar Dating. Unpublished PhD dissertation, University at Albany, SUNY. 397 pp.

Edwards, M.A., 1998. Examples of tectonic mechanisms for local contraction and exhumation of the leading edge of India. Southern Tibet (28-29N, 89-91E) and Nanga Parbat, Pakistan. Unpublished PhD dissertation, University at Albany, SUNY. 307 pp.

Edwards, M.A. and T.M. Harrison, 1997. When did the roof collapse? Late Miocene N-S extension in the High Himalaya revealed by Th-Pb monazite dating of the Khula Kangri granite. *Geology*, 25, 543-546.

Edwards, M.A., W. Kidd, and T.M. Harrison, 1995. Active Medial Miocene detachment in the high Himalayas of the Tibet-Bhutan frontier: a young crystallisation age for the Khula Kangri leucogranite pluton. *EOS, Trans. Amer. Geophys. Union*, 76, F567.

Harrison, T.M., P. Copeland, W.S.F. Kidd, and O. Lovera, 1995. Activation of the Nyainqentanghla shear zone: implications for uplift of the southern Tibetan Plateau. *Tectonics*, 14, 658-676.

Kidd, W.S.F., M. Edwards, Y. Yue, J. Li, C. Wu, K.D. Nelson, 1995. The END (East Nieru Detachment). A new low-angle mylonitic shear zone bordering the Yadong-Gulu rift system, southern Tibet. *Geol. Soc. Amer., Abstracts with Programs*, 27(6), A-337.

Li, J., B.V. Miller, K.D. Nelson, and S.D. Samson, 1998. Two belts of collisional granite in the Himalaya? *EOS, Trans. Amer. Geophys. Union*, 79(17), S350.

Ratschbacher, L., W. Frisch, G. Liu, and C. Chen, 1994. Distributed deformation in southern and western Tibet during and after India-Asia collision. *J. Geophys. Res.*, 99, 19917-19945.

Wu, C., K.D. Nelson, G. Wortman, S.D. Samson, Y. Yue, J. Li, W.S.F. Kidd, and M.A. Edwards, 1998. Yadong cross structure and South Tibetan Detachment in the east-central Himalaya (89-90E). *Tectonics*, 17, 28-45.

Summary of selected tectonic and geochronologic observations arising from the Nanga Parbat Continental Dynamics Project

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Introduction

The Nanga Parbat Continental Dynamics Project (c.f., Zeitler et al., this volume) employed various disciplines (e.g., Meltzer et al., this volume) to investigate the tectonic processes that have contributed/contribute to present situation at the Nanga Parbat Haramosh Massif (NPHM). This is a summary of some of our tectonic and geochronologic observations in Central and SE NPHM.

Astor valley and SE NPHM

Two antiforms (with broadly differing overall lithology) are observed in the main Astor Gorge; the Burdish Ridge and Dichil antiforms, in the west and east, respectively. The Burdish Ridge antiform is asymmetric with a thinned E-limb, while the Dichil antiform is asymmetric with a thinned W-limb. This is recognised by a very tight, pinched fold morphology of the accompanying (Dashkin) synform. The Iskere gneiss (Madin, 1986; Madin et al., 1989; Treloar et al., 1991) is present near the core of, and west of, Burdish Ridge antiform as a series of 100's m to < 2 km sections interlayered with the porphyroclastic and coarsely to finely laminated, occasionally calc-silicate gneisses. We suggest that the discontinuous nature of the Iskere gneiss in Astor Gorge compared to the Indus Gorge (ibid.) is largely due to "fingering" (thinning / pinching out of multiple tabular or elongated peripheral portions) of the edge of the main body that is seen along the Indus Gorge, and we note that the bodies should, in principle, be traceable northward to join the Indus Gorge main body (possibly in a non-continuous fashion, if certain Iskere layers are km-scale boudins or lenses). The original intrusive contact of the Iskere protolith may have been either inter-fingering or may have been planar.

The Dichil antiform includes various conspicuous gneisses and schists that can be followed (discontinuously) through the (~W-E trending) valleys of SE NPHM, including (e.g.) the "lath unit" (Edwards, 1998; Edwards & Kidd, this volume; Schneider et al., this volume; Argles et al., this volume; Foster et al., this volume). These form the footwall of the original MMT and present therein are impressive high strain zones related to both original MMT thrust-sense, and, locally, to MMT-normal sense (!) displacement (ibid.). There is no significant displacement fabric related to the uplift of NPHM, only overturning of the previous "high Himalayan" fabric that is part of the "bulging out" of southern NPHM.

NPHM-uplift-related shear zones in the SE

The Rupal-Chichi shear zone (RCSZ) is a km-scale, dextral, W-side up, high strain zone defined by a continuous belt of non-coaxially sheared granitic orthogneiss with impressive C/S fabrics along its entire length. This hitherto unrecognised feature is a fundamentally important discovery for constraining the tectonics of NPHM; it is now clear that the RCSZ has acted as the conjugate, "retro-" shear zone to the southern Raikhot & Diamir shear zone system (see below) to define a crustal scale pop-up structure. Displacement along the RCSZ may have migrated "inwards" to the centre of the massif based upon the ages of (1) cross-cutting leucocratic\-granitic dykes, and (2) total fusion Ar/Ar biotite-cooling ages of the orthogneiss, both of which show an overall younging towards the centre of the massif (Schneider et al., this volume - a & b). To the south of the RCSZ is the newly discovered early Miocene Southern Chichi leucogranite pluton (ibid.).

Shonthar Thrust

North and east of the Southern Chichi pluton, the cover sequences are marked by extensive marbles, amphibolites and metapelites of local Indian plate cover sequences. The foliation here switches from NW dipping (overturned) in northern Chichi, through vertical, to SE-dipping in southern Chichi. This may mark the southern limit of the NPHM "bulging out". Within the locally SE-dipping marbles & amphibolites, several reverse faults define a >200m wide, NW-vergent thrust zone. This is expressed by a clear box fold (box = 10's m area of section) within the zone. The thrust is observed to continue SW over the southern wall of Chichi Nullah. Its surface trace can be drawn from here and confidently joined with the Shonthar (Gali) thrust that has been mapped in Azad Kashmir near the Pak-Indo Line of Control.

Deformation in Rupal

Normal structures (top-to-NNW) are seen throughout Rupal valley. All, however, are brittle, probably very late, and of minor displacement. Most are developed on older thrust planes that are ~W-E trending; the western portion of the Rupal Chichi Shear Zone (RCSZ). There are vast thickness of orthogneiss in Rupal showing top to SSE thrust sense-of-shear. The NW-dipping fabric is continuous throughout the Rupal Face; biotite gneiss dips ~45°NW at the summit of Nanga Parbat. Locally, a ~2 km thick leucogranite with irregular margins intrudes the very steep western Rupal Face, above Shaigiri village (between ~5000 & ~6800 m). This may be emplaced in the axial zone of a tight antiform with NW-dipping axial surface, and whose axial trace passes to the south side of the summit ridge. This antiform is seen on Chongra ridge (again NW-dipping) and can be traced to the "western antiform" described from the Astor Gorge. In both of the valley walls, amphibolite, coloured marbles and metapelites are found as fairly homogeneously deformed metre-scale layers/lenses within the extensive orthogneisses. At lowest elevations in the valleys walls of central Rupal, numerous thick fault gouge zones are seen, possibly indicating that at least part of Rupal valley has provided a (topographic) local crustal weakness to focus late brittle deformation. In the southern portions of western Rupal (in Shagin Glacier valley, and all along the south side of Rupal & Toshain Glaciers) gnessic fabric dips SW to S and shows excellent SW stretching lineation, typically with a clear top-to-SSW sense of shear. Intrusive, now-L-tectonised granite pods pre-date this fabric. The orientation, petrographic texture, and sense of shear of the fabric resembles the mylonitic and high strain zones of the MMT footwall that we see elsewhere. We note that the top-to-SSW sense of shear is best explained by rotation (from ~N-dipping) of the original MMT thrust-displacement fabric; such a rotation is to be anticipated here on the SW flank of the uplifting massif.

The brittle normal faulting seen in a number of places in the massif indicates that the central part of southern NPHM is in a state of extension near the surface. It seems that there is a small value for normal stress on existing fractures of many orientations, and that only a small rotation of the stress field is required to switch from reverse to normal motion on pre-existing fault surfaces. Some focal mechanisms for resolvable seismic events within southern NPHM are consistent, showing extensional first motions occurring to ~6 km depth (Meltzer et al., this volume). Note, however, that there is no evidence for large-scale tectonic exhumation of NPHM.

References

Argles, T., M.A. Edwards, and G. Foster, this volume, Structural and Metamorphic Constraints on the Evolution of the Main Mantle Thrust, Eastern Margin of the Nanga Parbat-Haramosh Massif, N. Pakistan

Edwards, M.A. and W.S.F. Kidd, this volume, New Map of Southern Nanga Parbat.

Edwards, M.A., 1998, Examples of tectonic mechanisms for local contraction and exhumation of the leading edge of India, southern Tibet and Nanga Parbat, Pakistan. PhD dissertation, State University of New York at Albany, 308 p.

Foster, G., P. Kinny, D. Vance, N. Harris, T. Argles, A. Whittington, this issue, The pre-tertiary metamorphic history of the Nanga Parbat Haramosh Massif, Pakistan Himalaya.

Madin, I. P., 1986, Structure and neotectonics of the northwestern Nanga Parbat - Harramosh massif. Unpubl. MSc Thesis, Oregon State University, Oregon.

Madin, I.P., R.D. Lawrence, and S. Ur-Rehman, 1989, The northwestern Nanga Parbat Haramosh Massif; Evidence for crustal uplift at the northwestern corner of the Indian craton. *in* Malinconico, L. L. and Lillie, R. J., eds., Tectonics of the Western Himalayas, Geol. Soc. Am. Spec. Pap., 232: 169-182.

Meltzer, A., L. Seeber, G. Sarker, and J. Armbruster, this issue, Seismic Characterization of Active Metamorphism, Nanga Parbat, Pakistan Himalaya.

Schneider, D.A., M.A. Edwards, W.S.F. Kidd, and P.K. Zeitler, this volume-*a*, Geochronologic summary and lithotectonic architecture of the Nanga Parbat-Haramosh massif, NW Himalaya.

Schneider, D.A., M.A. Edwards, W.S.F. Kidd, P.K. Zeitler and C. Coath, this volume-*b* , Early Miocene anatexis identified in the western syntaxis: southern Nanga Parbat, Pakistan Himalaya.

Treloar, P. J., Potts, G. J., Wheeler, J. and Rex, D. C., 1991. Structural evolution and asymmetric uplift of the Nanga Parbat syntaxis, Pakistan Himalaya. Geol. Rund. 80: 411-428.

Zeitler, P. K. and 22 others, this volume, Geodynamics of the Nanga Parbat Massif, Pakistan Himalaya.

Summary of selected tectonic and geochronologic observations in SW NPHM arising from the Nanga Parbat Continental Dynamics Project

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Introduction

This abstract is a summary of some of our tectonic and geochronologic observations in SW NPHM arising from the Nanga Parbat Continental Dynamics Project (Zeitler et al., this issue).

Truncation of cover sequence

In the area that is encompassed by the N-S trending Bunar valley, and NW trending Diamir valley, the main fabrics trend mostly N to NNE. In this area, the Indian "cover" passive margin rocks that form the original MMT footwall include sequences of carbonates and amphibolites (probably the 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 to become 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. The hinge line and axial plane of the fold plunge gently N. South of this fold, the lower limb is exposed, thus sequences are not overturned and are observed to dip moderately to steeply west. The thickness of the cover sequence increases markedly to the south; carbonates, amphibolites and metapelites of several km of structural thickness are present in the W-E Airl-Nashkin section, 10 km to the south of Diamir valley.

The abrupt northward thinning of cover sequences in SW NPHM is orders of magnitude 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. Similarly, we have found no compelling evidence around NPHM for large-scale normal motion on the MMT (the MMT-normal motion seen in SE NPHM cannot account for several km of exhumation). Consequently, we suggest that a large-scale frontal ramp in the original MMT gave rise to a local duplex structure that imbricated thin slices of cover, and possibly basement. This model is consistent with our mapping in Niat Gah, the next main valley to the west of NPHM, where a basement slice occurring close to the MMT implies large-scale imbrication of the cover sequences.

Jalhari Granite synkinematic in Diamir Shear Zone

Structurally lower in the MMT footwall, and to the east, the cover sequence passes into a dominantly plutonic, ~5 km thick crystalline sequence that forms a continuous-along-strike (>30 km), ~N-S belt with vertical to steeply E-dipping fabrics. The Diamir and Airl Gah (both ~W-E) valleys offer almost continuous outcrop sections through the belt. From these valleys, it is clear that a coarse-, to medium-grained biotite granite (the Jalhari granite) grades into granitic and porphyroclastic gneiss due to syn- to post-plutonism deformation. Jalhari leucogranite lenses (10s - 100s m thick) showing little to no sub-solidus deformation are separated by 10's – 100's m thick layers of gneiss where deformation of the granite has been localised. These higher strain layers anastamose around the granite lenses, and mark reverse faults that climb to the west. The granitic gneiss shows significant sub-solidus strain, including S-C porphyroclastic fabric whose sense of shear consistently indicates east side (NPHM) up and over west. Well-developed ductile/brittle shear bands and local fault gouge horizons, both of the same range of

Terra Nostra, n. 2, 1999

14th
Himalaya-Karakoram-Tibet
Workshop

Abstract Volume

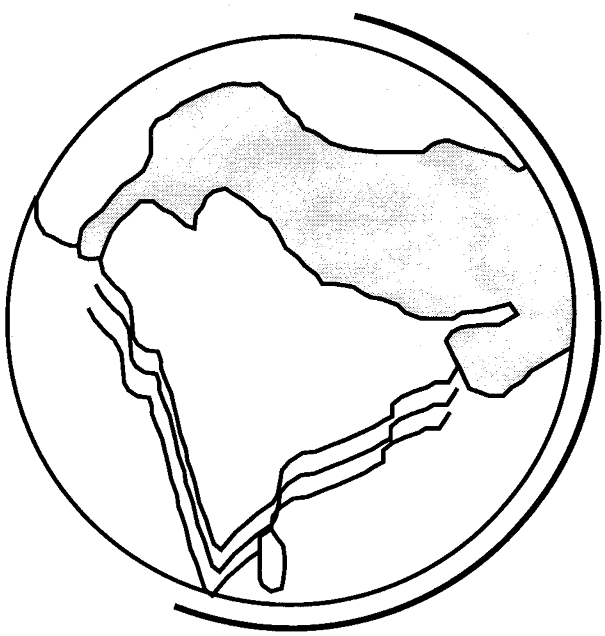
Editors:
Edward Sobel, Erwin Appel, Manfred Strecker,
Lothar Ratschbacher, and Peter Blisniuk

Kloster Ettal, Germany
March 24-26, 1999

TERRA NOSTRA

Schriften der Alfred-Wegener-Stiftung 99 / 2

14th Himalaya-Karakoram-Tibet Workshop



Kloster Ettal, Germany
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Organized by the Universities of Potsdam, Tübingen and Würzburg

Universität Potsdam (Germany)

Eberhard-Karls-Universität Tübingen (Germany)

Bayerische Julius-Maximilian-Universität Würzburg (Germany)

Impressum

Terra Nostra, 99/2: 14th Himalaya-Karakoram-Tibet Workshop, Kloster Ettal Germany

Herausgeber:
Alfred-Wegener-Striftung, Weyerstr. 34-40, 50676 Köln
Telefon: 49-(0)221-921 54190, Telefax: 49-(0)221-921 8254

Schriftleitung:
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Redaktion und Layout:
Edward Sobel

Druck:
Audiovisuelles Zentrum der Universität Potsdam
Am Neuen Palais 10
14469 Potsdam

ISSN 0946-8978

Selbstverlag der Alfred-Wegener-Stiftung, Köln, (1999)
Printed in Germany

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