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Structural and Tectonic Geology of the Namche Barwa-Gyala Peri antiform, SE Tibet

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Geological setting of the NB-GP massif (See map and cross-sections)

The Namche Barwa-Gyala Peri antiform, and its continuation to the southwest, are defined by the exposure of Indian-derived rock units through the cover and basement of the Lhasa block. The core of the antiform consists of largely quartzofeldspathic gneisses (pale tan colour) including a belt of distinctive garnet-rich rocks (tan colour), reworked Indian basement. A mostly continuous but narrow and highly-strained belt of metasedimentary gneisses and schists, including quartzites, calc-silicate gneisses and marbles, and pelitic schists surrounds the core (blue on map and sections) interpreted as metamorphosed Tethyan marine deposits of the underthrust Indian passive margin. An adjacent narrow discontinuous belt of highly-strained mafic gneisses (shown a darker green) represents the ophiolitic materials of the Indus-Tsangpo suture. Basement of the Lhasa block is identified as largely quartzofeldspathic gneisses (red colour) occurring outside this zone along the western side of the NB-GP antiform from near Loulan and around the steeply-plunging northern end of the antiform, and eastward along the Jiali Fault zone. Paleozoic-Mesozoic cover rocks of the Lhasa block consist of metasedimentary marbles, calc-silicates and quartzofeldspathic schists and gneisses (medium green) which pass up transitionally into low-grade phyllites and slates (pale green), with arenites/quartzites (yellow) and some limestones. All Lhasa block units are intruded by extensive granitoid plutons of the Gangdese Batholith (shown pink).

Nam-la thrust zone migmatites.
Left - north of Pai, view to east, in zone also strongly affected by faults and retrogression.
Right - SW of Pai, view to west, thrust sense ductile shear.

Nam-la Thrust zone

The Namche Barwa-Gyala Peri antiform is shown by our field mapping and sample analysis to have two parts, separated by a major north-dipping crustal-scale shear zone and fault, the Nam-la thrust zone.
See the geological map and the south part of cross-section A
The oldest detected parts of this thrust zone are amphibo lite-grade ductile shear involved with abundant dioritic migmatites (photos above); it later progressed through s/c mylonites, and into brittle faulting localised on the northern side of the zone. Cooling ages (Zeitler et al in tomorrow's oral session) show that the northern part of the NB-GP antiform was very recently and rapidly exhumed (e.g. all biotites <2Ma) , and we suggest that the thrust is directly linked to this exhumation and is still active.

Left - First rapids on the Tsangpo north of Pai; view SW
Nam-la thrust zone crosses the river here
Right - porphyroclastic mylonite in the ductile part of the western border shear zone in Deu'Gungbu valley. See cross-section D.
View south, thrust sense shear (east side up).

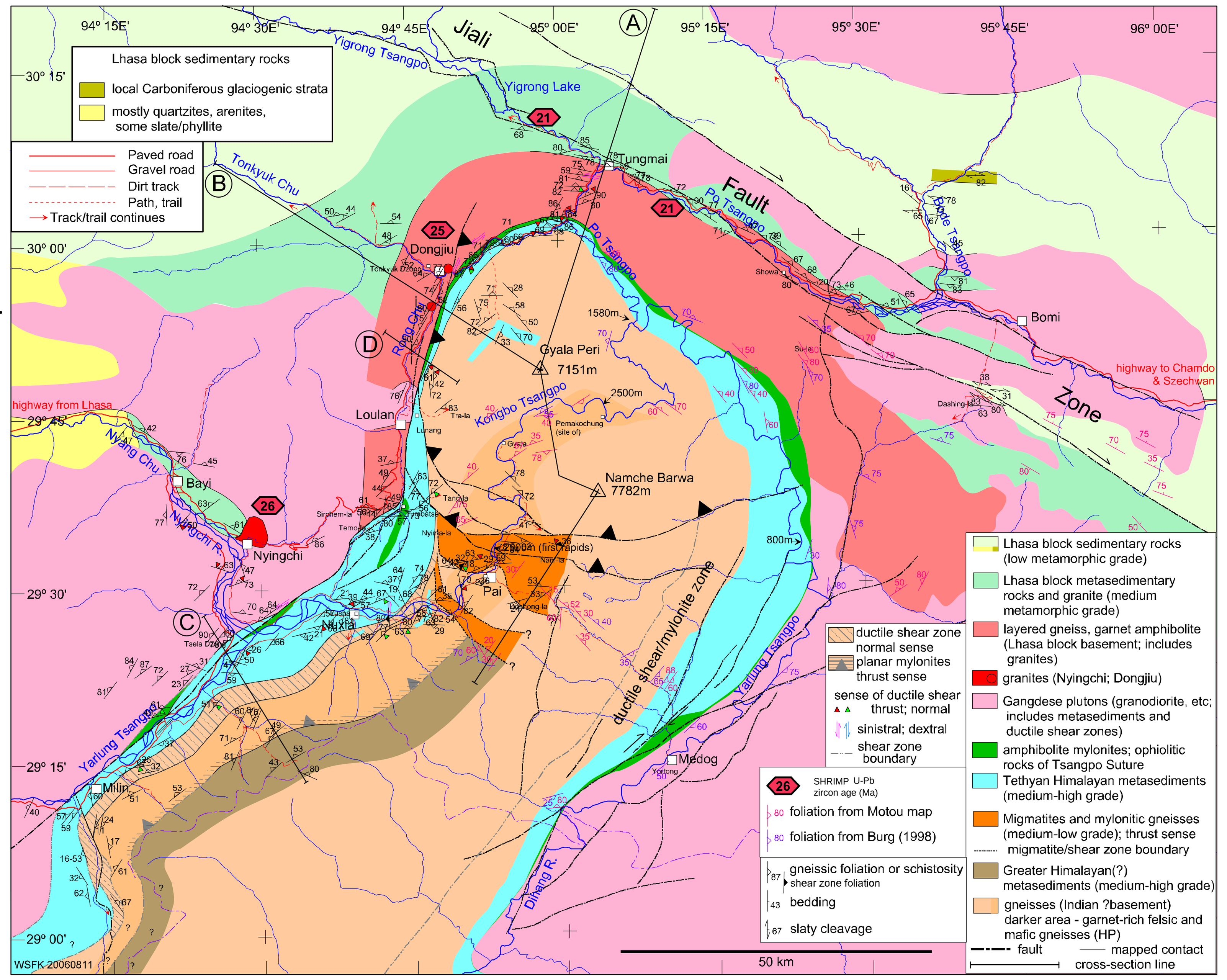
Western border of the NB-GP massif

The Nam-la thrust crosses the Tsangpo at the first major knickpoint (photo above) and passes northwest into the marginal thrust fault and shear zone bounding the Gyala Peri massif.
The western boundary of the Namche Barwa-Gyala Peri (NB-GP) structure has been mapped north along the eastern side of the Loulan Valley, defined by Lhasa block basement gneisses and garnet amphibolites to the west, and a narrow but traceable amphibolitic and metasedimentary mylonite zone (see sections B and D, and map) interpreted to be the modified remains of the India-Asia suture and Tethyan sedimentary rocks of the Indian margin. Porphyroclastic and layered grey g neisses in the eastern part and east of the mylonite zone (photo above) are interpreted as Indian continental crustal rocks uplifted by the NB-GP structure.
A well-defined zone of brittle faulting up to a kilometer wide borders the west side of the amphibolitic mylonites, with dominant E-side up thrust faults (see cross-section D). This zone represents the present active western margin of the NB-GP structure, and the progression from ductile mylonites to brittle faults expresses the progressive exhumation of the rocks from deeper to shallow levels in the shear zone bordering the N B-GP massif. Fault slickensides and the mylonite stretching lineation are steep and dominantly of thrust sense in present orientation (see lineation map). Indications of significant strike-slip displacement on this structure are not found.

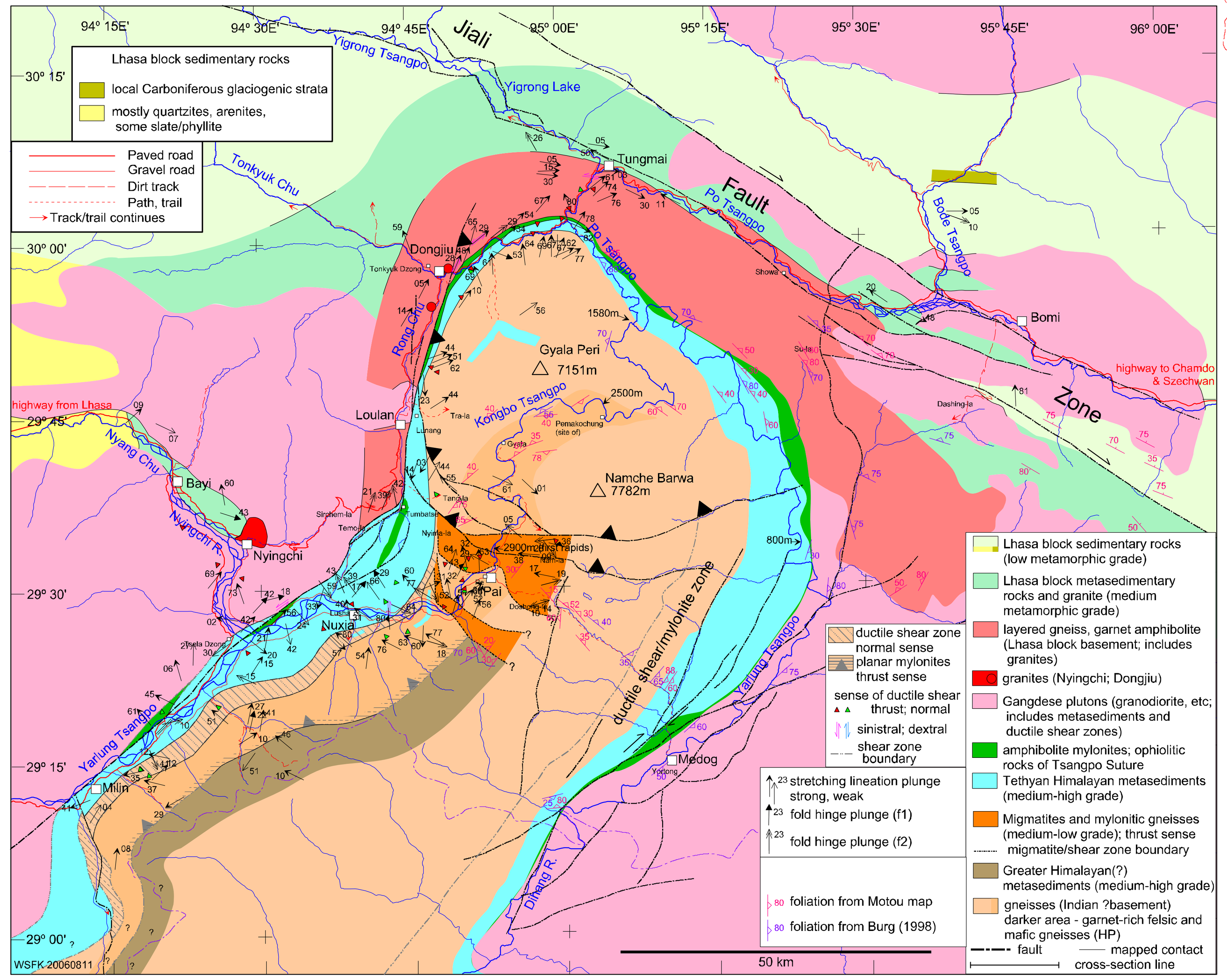
Older ductile shear structures

Most ductile shear indicators seen in Lhasa block gneisses and the Gangdese grantoids are thrust sense, perhaps related to the early-Miocene Gangdese Thrust, and/or older event(s). Dated 20-25Ma granites near Dongjiu and Tungmai (see map, and photo to right) cut these fabrics. Southwest of the NB-GP massif, the Himalayan Tethyan metasediments near the attenuated Indus-Tsangpo ophiolitic suture contain some thrust sense ductile shear indicators, probably related to Himalayan (under)thrusting.

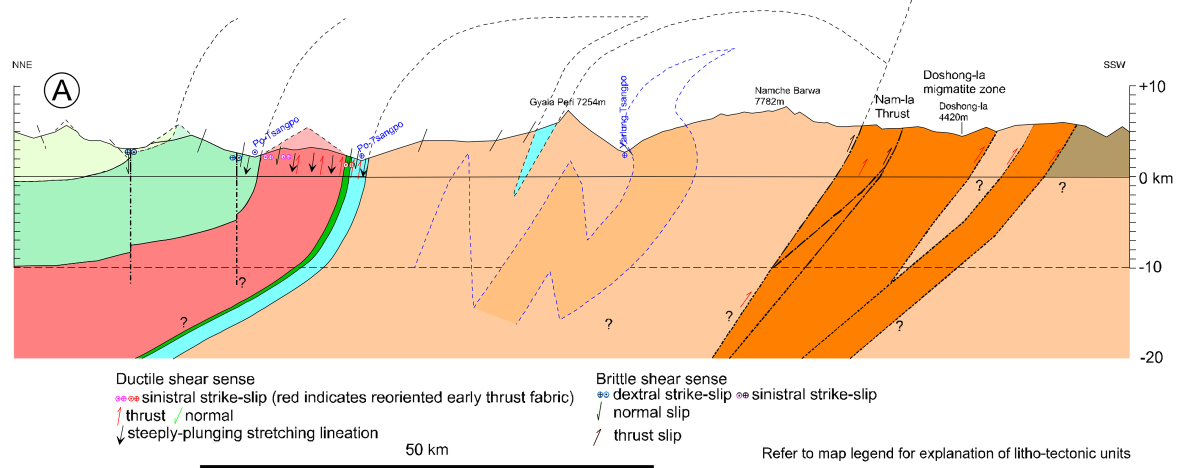
Porphyroclastic granitoid gneisses with amphibolites (Lhasa block basement) crosscut by granite dike (arrowed) of 21Ma age suite. Po Tsangpo-Yigong Tsangpo confluence

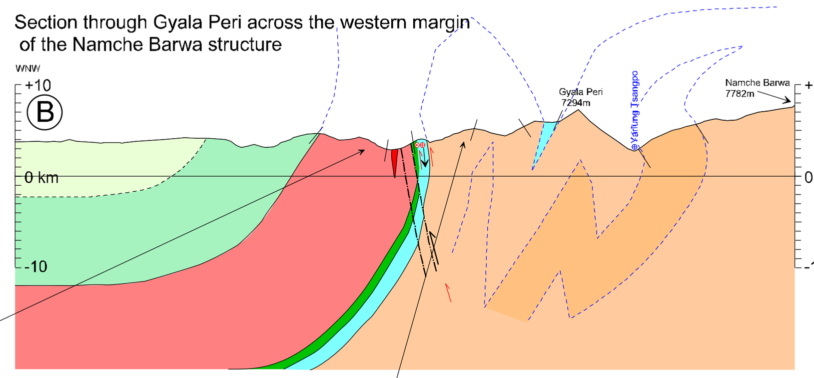


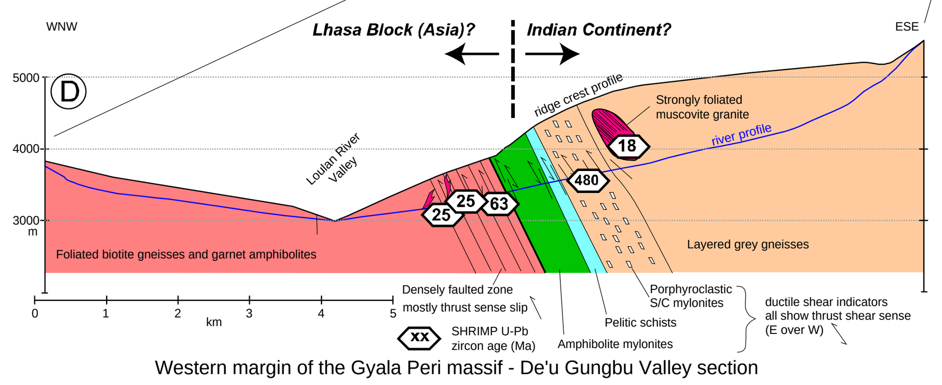
Geological map of the Namche Barwa-Gyala Peri structure with ductile foliation data, and cross-section locations.



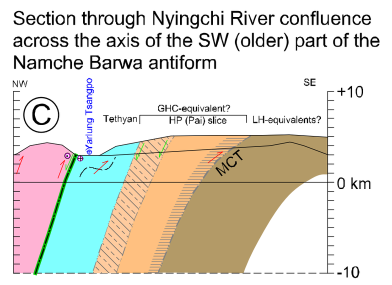
Geological map of the Namche Barwa-Gyala Peri structure with ductile lineation and shear sense data.







Detailed cross-section of the western margin of the Gyala Peri massif at the De'u Gungbu Valley (see map for location). V=H scale.



Normal-sense ductile shear - STDS?

Evidence for north-down normal sense shear in amphibolites and associated rocks along the attenuated Indus-Tsangpo ophiolitic suture, and also in the Tethyan Himalayan metasediments, has been seen in some places, and perhaps in the Lhasa block basement south of Tungmai (see lineation map, to left). This may be evidence of early or mid-Miocene South Tibet Detachment System-related extension, but we have not found suitable rocks to date this fabric.
Total thickness estimated for the Lhasa basement and cover before NB-GP uplift (20-25km - see section A), and the attenuated and highly-strained condition of the Tethyan and suture rocks suggests that significant crustal thinning occurred before the present geometry was established, and STDS-related extension localised in this zone would accomplish this.

Jiali Fault zone and the NB-GP northern margin

The northern end of the NB-GP antiform plunge s steeply north, producing a large-scale monoclinal fold in the Lhasa block basement and metasedimentary cover schists and gneisses (see section A, and the maps). The steep part of this fold is within the Jiali Fault Zone, and here right-lateral strike-slip brittle faulting is locally prominent. Ductile lineations in gneisses in the vicinity of the Jiali Fault zone are cut by 20-25 Ma granites, predate the monoclinal crustal fold which upturned these gneisses, and are thus unrelated to the right-lateral strain of the Jiali zone.

Differences from previous work

No evidence was found for a proposed detachment fault near Dongjiu, between gneisses of the Lhasa block and overlying sedimentary rocks; rather there is a metamorphic transition through a substantial section of amphibolite-grade metasedimentary rocks, which are cut by the 20-25Ma granites.
We find no evidence for the strike-slip faults previously placed along the purported locations of one or both of the NB-GP massif margins, and in the case of ductile structures with apparent strike-slip orientations, we think these are from reorientation by the uprise of the GP-NB antiform of older originally ~N-S oriented, gently-plunging underthrusting or STDS-type extension fabrics.

Acknowledgements

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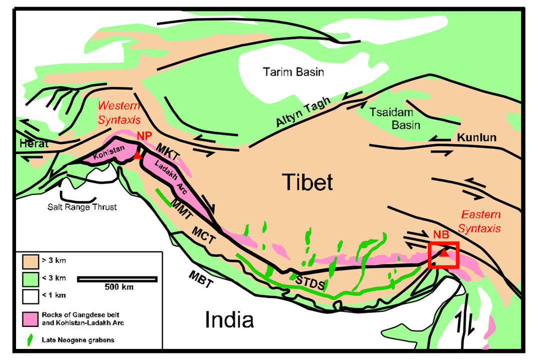


Location of Himalayan syntaxes
NB - Namche Barwa

View of Gyala Peri (7294m) from the Tsangpo river valley 80km SW of the peak. The sunlit south face is that in cross-sections A and B

Porphyroclastic mylonite with normal-sense shear (view to NE) on top of granulite belt. Near Milin.

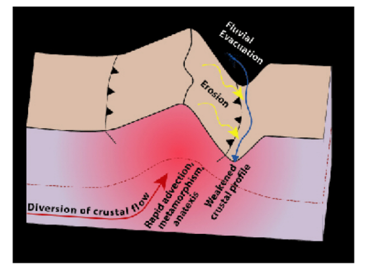
Granulite belt in the NB-GP antiform

Within the western side of the overall Namche Barwa antiform, a belt of variably retrograded granulite gneisses forms the upper part of the apparent Indian basement (see map and section C). This belt has a narrow thrust-sense mylonite zone along its southeastern (lower) contact (which may be the local equivalent of the Himalayan MCT), with amphibolite facies clastic metasediments below. Its northwestern contact zone with Tethyan quartzo se, pelitic and calcsilicate amphibolite facies schists is a normal-sense ductile shear zone (photo, above right). We interpret this belt as a crustal slice deeply-subducted and returned quickly to within the crust during the earliest stages of the Himalayan collision, its sh ear zone contacts probably related to this upward return.
This belt is cross-cut by the Nam-la shear zone. South and southwest of the Nam-la thrust and migmatite zone, biotite cooling ages of 4-10Ma show that growth of this extension of the Namche Barwa ant iformal structure was minimal after the latest Miocene.

Garnet-rich granulite gneiss from the interior of the NB-GP antiform.

Implications

Surface structural constraints require detachment of the NB-GP rocks from at least mid-crustal depths (cross-section A), but by themselves do not necessarily require that the Nam-la shear zone extend to the base of the present double-thickness crust.
The extensive development and involvement of migmatites with the early ductile shearing of the Nam-la shear zone can be interpreted to suggest that this magmatism was significant in localising, and perhaps in promoting the initiation of, the younger part of the GP-NB antiform, although this is not a well-tested hypothesis at present. It also does not preclude the idea that incision by the Dihang-Brahmaputra was the initial step in weakening the crust to start development of the larger syntaxial antiform.



Model for regional tectonic setting of syntaxial domal uplifts. The western margin of the NB-GP structure would be represented by the thrust fault in the left side of this figure

Landsat 7 Thematic Mapper image mosaic covering the same area as the geological map.
TM Bands 5,4,2:R,G,B. Images from October, November 2001.