Surface Geology of the Indepth I and II Seismic Profiles, Southern Tibet

T32B-6

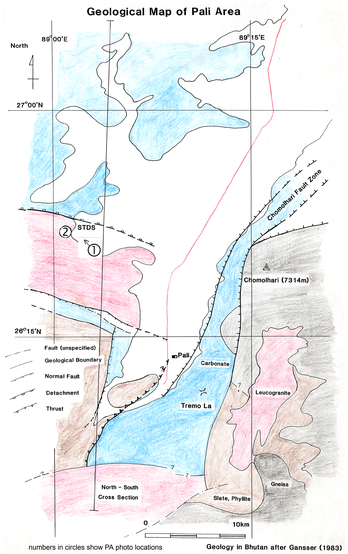
[1]Edwards, M., [1]Kidd, W., [2]Li, J., [2]Yue, Y., [3]Wu, C., and [4]Clark, M.
1- Dept of Geological Sciences, SUNY at Albany, Albany, NY 12222
2- Chinese Academy of Geological Sciences, Baiwanzhuang Road 26, Beijing 100037, PR China
3- Dept of Geology, Syracuse University, Syracuse, NY 13244
4- INSTOC, Snee Hall, Cornell University, Ithaca, NY 14853

Abstract
A composite surface geological profile, from near Yadong in the crystalline Himalaya north to near Gulu in the Lhasa block, will be presented for comparison with the INDEPTH I and II CMP seismic reflection profiles. Major ductile fault structures crossed by the surface profile which may correspond to some of the higher reflectors on the seismic lines include the Southern Tibet Detachment [STD], the Kangmar Detachment [KD], the Gangdese Thrust [GT], and the Nyainqentanglha detachment(s). South of Pumo Tso, the earlier ductile mylonites of the STD and associated leucogranite of Kula Kangri are domed and truncated by the later gently north-dipping capping fault of the detachment. This detachment is cut here by a significant E-W steeply N-dipping normal fault, in part of post-glacial age. Significant offset of the ductile STD by these two structures is inferred. We have identified an extension to the KD east of the Nieru [Jiabu] valley; early movement may have been northward like the KD. The hypothesis that the STD and the KD were once the same movement surface is permitted by our observations, although very different basement is exposed by each, and the cover sequences are of different facies. Disappearance of the Southern Tethyan sedimentary sequence eastward across the Yadong-Gala graben corresponds to the western limit of the E-W steep normal fault, and the appearance on its south side of a thick section of carbonate mylonites, at the southern end of the Jiabu valley, which we presume to be the attenuated equivalent of the S Tethyan sequence.

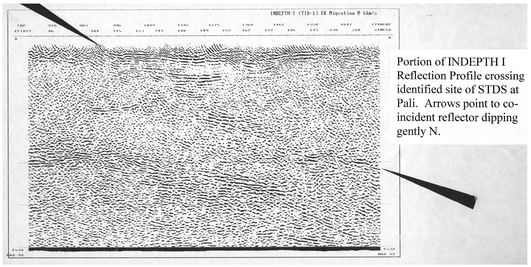
Location of the STDS near Pali; INDEPTH I line, Yadong Graben

The STDS near Pali, southern Yadong-Dogen Lake Graben

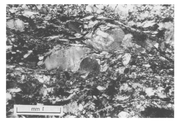
The location of the STDS (South Tibetan Detachment System) within exposures near the southern end of the Yadong-Dogen Lake Graben has been uncertain. We [Wu, Yue] have mapped a section northwest of Pali that we propose is the STDS, where highly foliated rocks, some of them S/C-type mylonites from granitoid and/or gneissic protoliths, underlie mildly deformed sedimentary rocks of the South Tethyan Himalyan belt. The detachment foliation dips ~23ºN, and contains down-to-north sense of shear indicators. The top of the detachment projects ESE to the INDEPTH I seismic line at about CDP 900-940, near the location of the Tanla Pass. A narrow band of somewhat discontinuous reflectors can be identified on the seismic profile rising to this position at a dip of 22º near the surface, from 3 seconds two way time [~9km depth] at CDP 1740 - for a larger context, see the companion display - Hauck et al.
Some of the confusion over the location of the STDS results from the occurrence of lower grade phyllitic and carbonate rocks to the southwest of the Tanla Pass. These lower grade rocks might underlie a thrust carrying the granitoid and gneissic rocks, or they could (as shown on the cross-section) define a shallow repetition of the STDS.
Structures in bedrock on the eastern margin of the Yadong-Dogen Lake Graben suggest that motion on the Chomolhari Fault, which bounds the graben, is dominantly of dip-slip character.



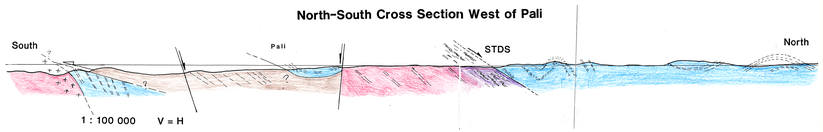
PA1 View looking north at the Zherger La detachment, approximately 5 km west northwest of Zherger La. The detachment separates Tethyan sandstones above (light grey making up far ridge) from mylonitic granite gneiss below (dark grey in near ridge)



Portion of INDEPTH I Reflection Profile crossing identified site of STDS at Pali. Arrows point to coincident reflector dipping gently N.



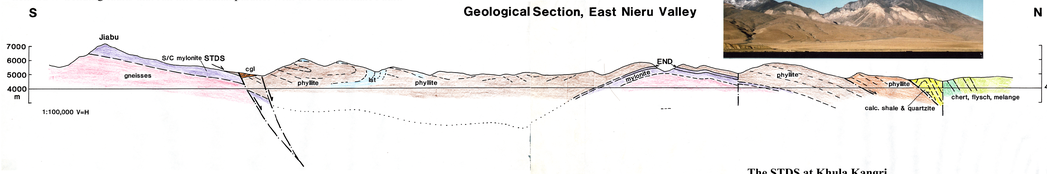
PA2 Photomicrograph of mylonitic granite in the immediate footwall of the Zherger La detachment, oriented approximately perpendicular to the mylonitic foliation and parallel to lineation. Large asymmetric grains are mica fish. S-C fabric indicates top-to-the north (right) sense of shear.



Detachments east and south of Nieru Valley Graben

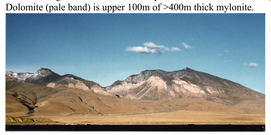
Top-to-north low-angle detachments in the Nieru [Gabo] Valley; STDS and END

STDS -- Southern Tibet Detachment System
The STDS is exposed at the south end of the Nieru Valley graben, where it consists of a thick [300-500m] mylonite derived dominantly from leucogranite. This zone dips ~20ºNNW, with S/C fabric showing top to N shear sense, above granitoid and mafic gneisses permeated by leucogranite. Brecciated carbonate rocks, presumed early Paleozoic, appear to lie above the detachment in the Wagye-la valley; farther west >300m of low-grade carbonate mylonites, dominated by late, top-to-N shear sense, overlie the granitoid and gneissic rocks to the south, and are adjoined by less deformed phyllitic and carbonate sedimentary rocks to the north. A prominent triangular-faceted mountain front defines the south end of the Nieru Valley graben. This, and other evidence of E-W trending faulting along strike, suggest the STDS is cut here by a north-down steep normal fault, as in the Khula Kangri region to the east. Relations of the STDS here are additionally complicated by prominent SSW-trending faults that run into Bhutan parallel with the Chomolhari Fault.

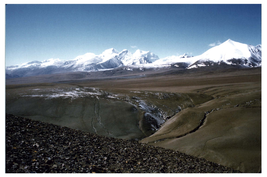


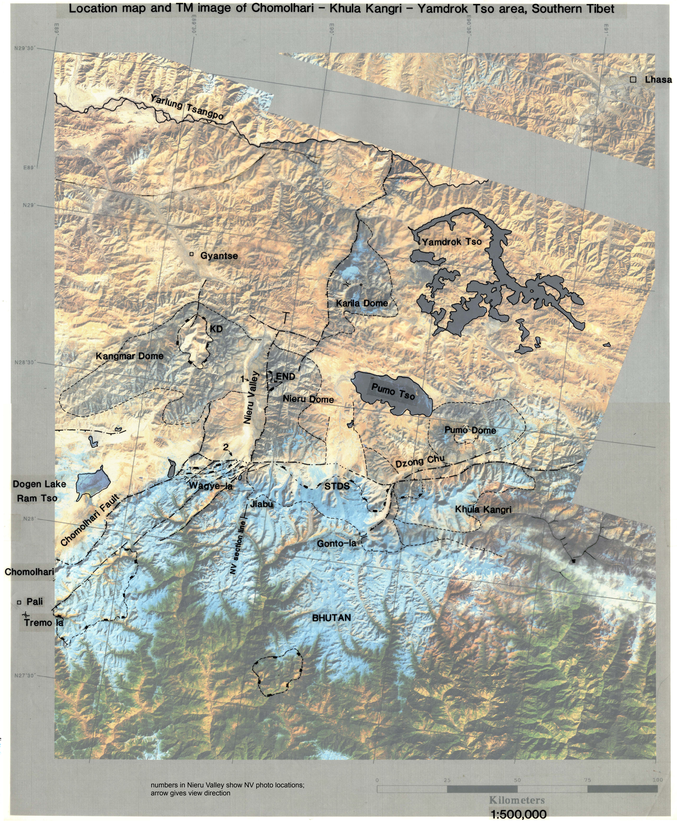
END -- East Nieru Detachment
The END is a significant extensional detachment on the eastern side of the central Nieru Valley. This is exposed in the culmination of a domal structure, mapped by us as an eastern continuation of the Kangmar Dome. A lenticular quartz vein breccia zone, typically a few meters thick, forms the brittle cap to the detachment, and carries low-grade dark phyllites of the late Paleozoic Tethyan sedimentary sequence. Below the brittle capping fault, ~100 meters of tan dolomite mylonite overlie a further ~300m of mylonite, of pelitic, quartzofeldspathic, and calc-silicate/carbonate origin. The metamorphic grade increases markedly towards the exposed base, although no intrusive granitoid rocks are exposed in the section. We interpret this detachment to be an eastern continuation of the Kangmar Detachment (KD). It suggests a vertical displacement of several km [~3km?] for the eastern bounding fault of the Nieru Valley Graben, based on down-plunge projection of the KD.

NV1 Looking east across Nieru Valley to East Nieru Detachment (END). Dolomite (pale band) is upper 100m of >400m thick mylonite.

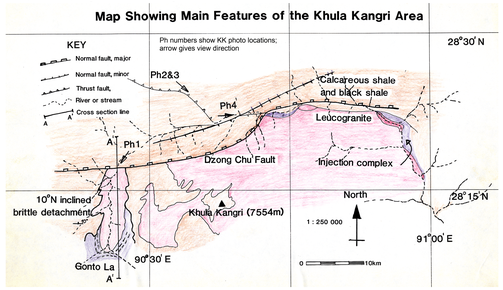


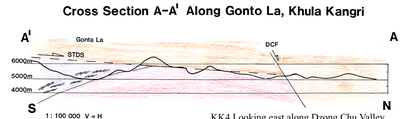
NV2 View to SE from southern end of Nieru Valley. Jiabu peak in left center. Gently N-dipping surface of STDS is visible to the east of Jiabu. Triangular facet of mountain on right suggests steep normal faulted southern border to Nieru Graben, and displacement of the STDS by this fault.





The STDS at Khula Kangri
The Khula Kangri leucogranite puton has an extent of at least 40km x 70km. On the eastern margin is an intrusive planar contact with black and red slates. At the contact, the granite is unfoliated and the country rock grades from amphibolite facies schists to slates across a narrow section (<100m). The extensive mylonite which characterises the STDS elsewhere is found nowhere along the east margin of Khula Kangri, nor are Tethyan sediments observed juxtaposed against gneissose crystalline basement.
On the western margin at Gonto La the leucogranite is in contact with a thick section (>800m) of mylonitic, leucogranite sill-bearing metasediments. Fold asymmetry in leucogranite sills shows top-to-N shear sense. Layering of the metasediments dips gently to steeply southwards, is parallel with the leucogranite contact, and forms the southern limb of a cylindrical anticline. The crest of the fold and the north limb are truncated by a brittle detachment which dips ~10º @010º and places subhorizontal dark shale sequences over the metasediments and leucogranite. The detachment is truncated to the N by a large E-W normal fault system of >60km in length which parallels the Dzong Chu valley.
The metasedimentary layers with top N sense of shear are regarded as the thick mylonitic sequences which characterise the ductile stages of the STDS. Their domed contact with the leucogranite may be due to pluton rise late in STDS history, which domed the STDS mylonites and rotated the observed section in Gonto La to its present, S-dipping attitude. Rise of the pluton here ceased before final stages of N-S extension which created the truncating brittle detachment. We propose that, to the E, emplacement of the pluton outlasted N-S extension and obliterated structures of the STDS by intrusion.

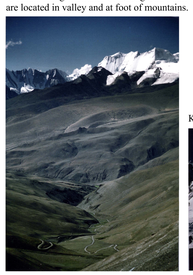




KK1 View of brittle STDS looking SW into Gonto La Valley. Note flat lying slates juxtaposed over leucogranite.

KK4 Looking east along Dzong Chu Valley. Strand of Dzong Chu fault follows scarp on south side of valley. Leucogranite boulders in foreground came off Khula Kangri.

KK2 Looking SSW across Dzong Chu Valley to Khula Kangri. Strands of Dzong Chu Fault are located in valley and at foot of mountains.



KK3 View of north face of Khula Kangri.

Discussion

The TIB-3 seismic profile is interpreted [see the companion display - Hauck et al] to image the KD/END as the first identifiable reflector, and may imply that the KD/END is the same detachment as the STDS. This is in spite of the conspicuously different appearance of the detachment exposures: Kangmar, where dark phyllites rest on a narrow [10's of meters] zone of metasedimentary mylonites over rodded basement granite [562Ma]; East Nieru, where dark phyllites lie above a thick zone (>400m) of metasedimentary mylonites capped by a brittle fault; and South Nieru - the STDS - where >300m of S/C mylonites derived from Neogene leucogranites form the bulk of the zone, with an inferred brittle capping fault separating them from brecciated carbonates and phyllites.

Both in the southern Nieru Valley and in the Khula Kangri area there is evidence that the STDS is cut by a significant E-W trending, down-to-north steep normal fault. In Khula Kangri, this is in part post-glacial, but in Nieru the fault does not cut moraines. The TIB-3 [Nieru Valley] seismic profile shows [see the companion display - Hauck et al] that a reflector projects south from the southern end of the line towards the outcrop of the STDS, but the extrapolation permits perhaps a kilometer or two of displacement on a normal fault bounding the south end of the main graben valley. A non-trivial thickness of Quaternary fill in the southern end of the valley is estimated from the seismic data and supports the idea of such a fault.

We connect the east-west trending steep normal fault system, identified along the Dzong Chu near Khula Kangri, and across the southern end of the Nieru Graben, to the major fault [Chomolhari Fault] bounding the east side of the Yadong-Dogen Lake graben. We suggest that the Chomolhari Fault, and its proposed continuation as the Dzong Chu and related faults, have permitted a greater amount of late Neogene and Quaternary uplift and denudation of the Bhutan Himalaya compared with areas west of the Chomolhari Fault, and is part of the explanation for the abrupt eastward disappearance of the southern Tethyan Himalyan sedimentary sequence. We presume that the Chomolhari structure is controlled by a significant discontinuity in the underthrusting Indian shield, e.g. a lateral ramp in the MHT.

Acknowledgements
This contribution to the INDEPTH project funded by Continental Dynamics Program, National Science Foundation.
The authors wish to thank all participants of INDEPTH II for their assistance in making the field work possible and for free discussion of ideas.