Geologic evolution of the Gyala Peri Massif, southeastern Tibet

Kidd, W.S.F.[1], Zeitler, P.K.[2], Meltzer, A.S.[2], Lim, C.[1], Chamberlain, C.P.[3], Zheng L.[4], Geng Q.[4], and Tang, Z.[4]
[1]Earth and Atmospheric Sciences, Univ. at Albany, Albany NY 12222 USA <wkidd@atmos.albany.edu>
[2]Earth and Environmental Sciences, Lehigh University, Bethlehem, PA 18015 USA
[3]Geological Sciences, Stanford University, Stanford CA 94305 USA
[4]Chengdu Institute of Geology and Mineral Resources, 3/82 no.1 Ring Road N, Chengdu, SZ 610082 China

Abstract

At both the eastern and western terminations of the Himalaya, strong coupling between surface and tectonic processes is manifested in the development of active antiforms in close proximity to large river gorges. In southeastern Tibet the peaks Gyala Peri and Namche Barwa occupy a metamorphic massif that shows remarkable similarities to the Nanga Parbat massif in NW Pakistan, including exposure of high-grade gneisses intruded by Plio-Pleistocene granites. Nanga Parbat has been proposed to constitute a 'tectonic aneurysm' involving erosionally focused strain and related metamorphic reworking. As the Namche Barwa/ Gyala Peri massif appears to be quite similar to Nanga Parbat in its geology and geologic setting, we suggest it has a similar origin. Most information to date has been reported from Namche Barwa, with Gyala Peri remaining largely unexplored. Here we report observations from a well-exposed section along the western margin of Gyala Peri. In the west near the Loulan River, a brittle fault zone up to ~1 km wide juxtaposes a metasedimentary/mylonite section on the east against Lhasa/Gangdese gneisses and granitoid rocks to the west. The steeply dipping fault zone shows a dominantly east-up (reverse) sense of brittle motion. The lower portion of the Lhasa/Gangdese metamorphic section is cut by dikes of at least two granite phases, a medium-grained Gangdese-like granite, and a leucocratic pegmatite. East of the brittle fault zone, and the metasediments and planar foliated mylonites, there is an ~500 m thick section of S/C mylonites having a dominant reverse and subordinate dextral sense of shear. East of, or possibly in the eastern part of this ductile fault, grey gneisses [presumed basement] are intruded by a syntectonic(?) muscovite granite. Ar-Ar K-feldspar data from Gangdese rocks just west of the brittle fault zone drop to ages of 4 Ma, substantially younger than the pattern seen further to the west at Bayi. Overall, the geology of this section is quite similar to the western margin of the Nanga Parbat massif and, like it, represents progressive displacement and exhumation on a significant thrust sense shear and fault zone bordering the Gyala Peri massif. U-Pb analyses of the granites and the mylonite will be reported along with data from a pilot seismic study that had stations located in proximity to Gyala Peri.

Geology and structure

A. The western boundary of the Namche Barwa-Gyala Peri (NB-GP) structure has been mapped (Figs 3,5) north along the eastern side of the Loulan Valley, defined by gneisses and garnet amphibolites to the west (proposed to be Lhasa block basement), and a narrow but traceable amphibolitic and metasedimentary mylonite zone (see section of Fig 2, and map of Fig 5) interpreted to be the modified remains of the India-Asia suture and Tethyan sedimentary rocks of the Indian margin. Porphyroclastic and layered grey gneisses in the eastern part and east of the mylonite zone are interpreted as Indian continental crustal rocks uplifted by the NB-GP structure (Fig. 2 cross-section).
B. 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 Fig. 2 cross-section, and structural data on fig 5 below). 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 NB-GP massif. Fault slickensides and the mylonite stretching lineation (Fig. 5) are steep and dominantly of thrust sense in present orientation (Fig. 2). Indications of significant strike-slip displacement on this structure are not found.
C. No evidence was found for a proposed detachment fault near Dongjiu, between gneisses of the Lhasa block and the metasedimentary rocks of the Lhasa block which adjoin it.

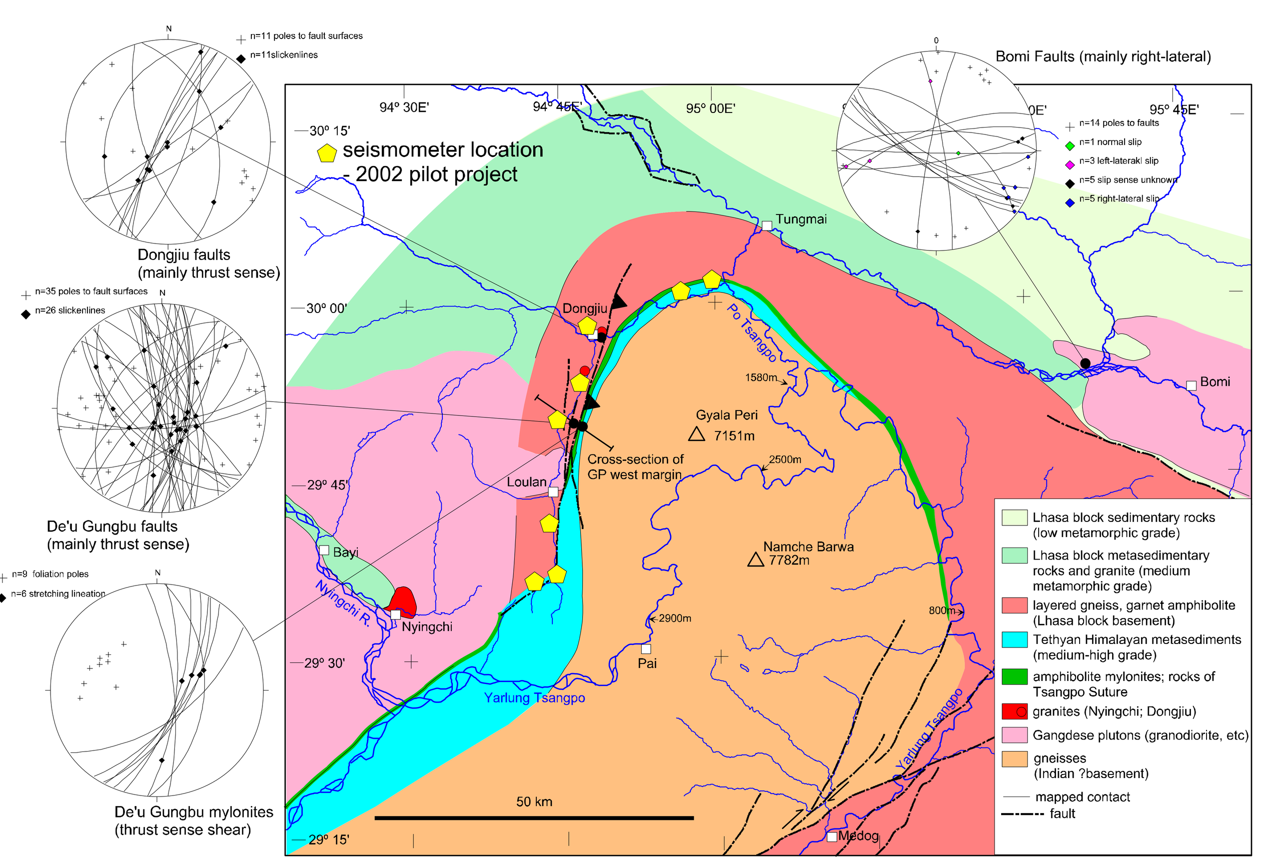


Fig. 5 Geological sketch map of Fig 3 with lower hemisphere stereographic projections of structural data from the fault and ductile shear zone on the western border of the Gyala Peri massif, and a locality in the Jiali fault zone near Bomi. Location of seismometer

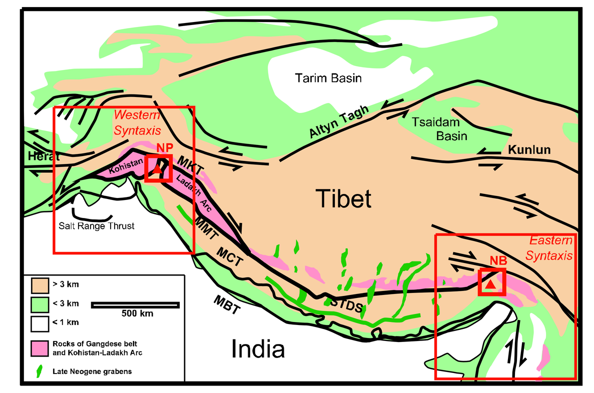
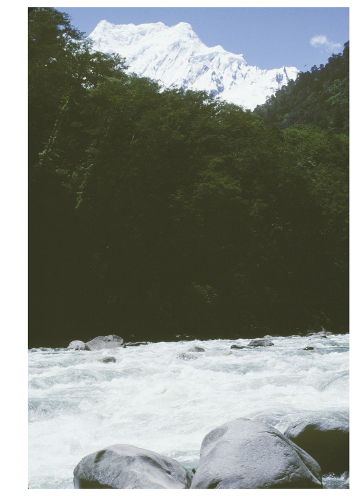


Fig 1. Tectonic sketch map with location of Himalayan syntaxes



Western part of the Gyala Peri massif seen from the north, on the Parlung River

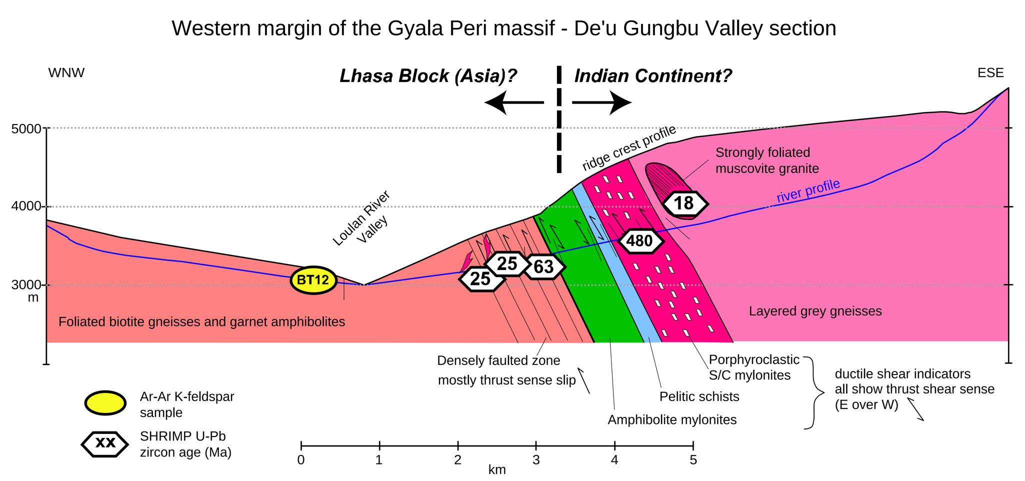


Fig. 2. Cross-section of the western margin of the Gyala Peri massif at the De'u Gungbu Valley (see map of fig 3 for location). V=H scale.

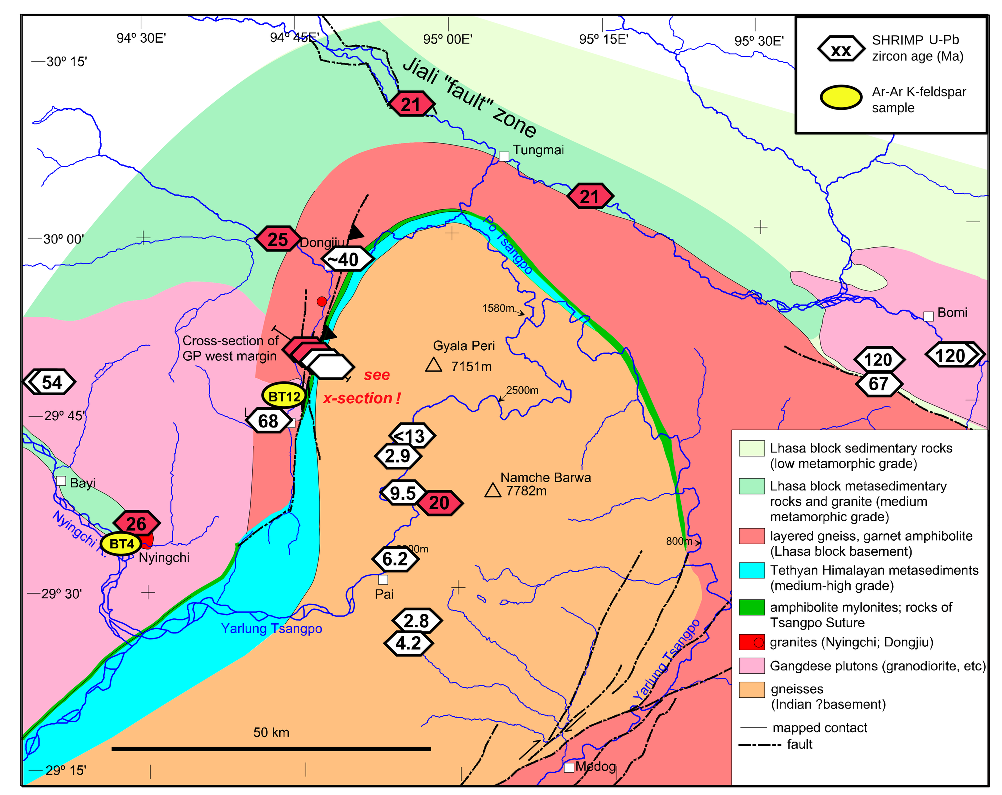


Fig. 3. Geological sketch map of the Namche Barwa-Gyala Peri structure. Isotopic age results shown are confined to those of this project.

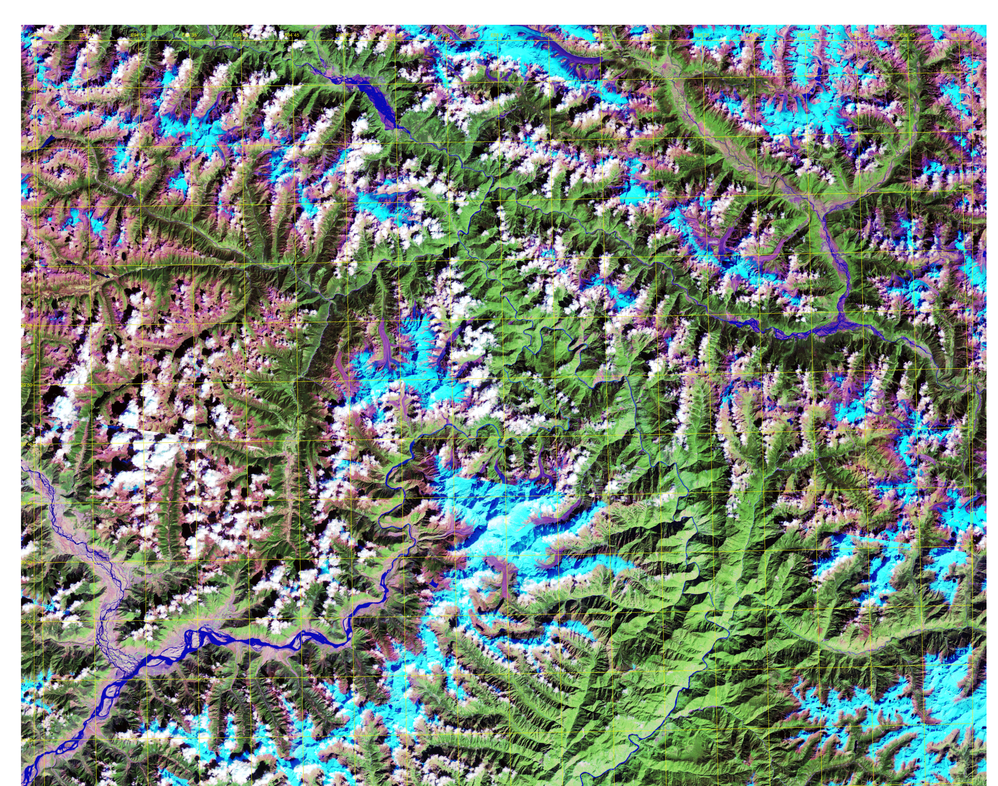


Fig 4. Landsat 7 Thematic Mapper images covering the same area as the geological map. Bands 5,4,2:R,G,B. Images from 23 Sept and 25 Oct 1999.

Geochronology

We report provisional zircon U-Pb ages from southeastern Tibet which provide a evolutionary context for the Gyala Peri massif, as well as two Ar-Ar K-feldspar dates which bear on the exhumation history of the region (detailed cooling-age measurements across structures are in progress but were not available in time for this meeting). The zircon ages were obtained on the Stanford SHRIMP RG instrument.

U-Pb Results, Gyala Peri Transect. We dated zircons from five samples: two meter-scale dikes cross-cutting the western, Lhasa-Block portion of the section, a sample of granitoid basement from near the dikes, the S/C mylonite, and a foliated, muscovite granite that occurs at the very top of the section (Fig 2).

The westernmost dike is a medium fine-grained granite; the other is a leucocratic pegmatite. Zircons from both dikes yield ages of about 25 Ma, but contain cores that yield different ages of, respectively, about mid-Proterozoic and Cretaceous. Zircons from the sample of granitoid basement yield a tight cluster of ages of 63 Ma, with no evidence for an inherited component. The S/C mylonite protolith is about 480 Ma in age, with no evidence for inheritance. Finally, the muscovite granite contains very low-U, very low Th/U zircons (~20 ppm) that are about 18 Ma in age; a few grains with higher U and higher Th/U show minor inheritance in the form of discordant ~100 Ma ages.

Regional U-Pb Results. To provide constraints for geologic studies and context for thermochronological measurements, we have been dating igneous units throughout southeastern Tibet. As shown on Figures 3 and 2, almost all the zircon U-Pb ages fall into four broad groupings: ~120 Ma, 50-70 Ma, 18-26 Ma, and << 10 Ma. One exception is a garnet granite near Dongjiu that shows a complex distribution of U-Pb ages and 40 Ma is only a provisional estimate. The second exception is a mylonitic orthogneiss exposed in the Gungbu section, which contains zircons clustering around 480 Ma.

The first two groupings of samples are clearly related to "Gangdese" arc magmatism. At the other extreme, the very young ages found within the core of the Namche Barwa antiform are consistent with suggestions that this structure, like Nanga Parbat in the NW Himalaya, is metamorphic hotspot attributable to erosional focusing of strain ("tectonic aneurysm" model - Fig. 10).

The ages ranging between ~20 to 25 Ma are quite unexpected from rocks that had previously been assumed to be Lhasa Block gneisses and Gangdese granitoids. Compared to zircons from the Gangdese suite, all the 20-25 Ma samples contain both igneous zircons with low Th/U as well as distinct inheritance in the form of both Proterozoic and/or Gangdese components. This suggests that these are partial melts of local basement. The distribution of these anatectic rocks from the core of the Namche Barwa massif, across towards Bayi, and up to the Jiali Fault Zone across the Gyala Peri massif, in turn suggests a rather significant, widespread Oligocene-Miocene metamorphic event affected the already-sutured Indian plates and Lhasa Block. Evidence for juxtaposition of these two terranes may in fact be found along the Gungbu transect, as the lower portions appear to be Lhasa Block, whereas the 480 Ma orthogneiss crops outs immediately to the east across amphibolite mylonites, and such porphyritic granites of Pan-African age are widespread in the Lesser Himalaya (e.g., Mansehra granite, Pakistan).

Ar-Ar-Results. We have reconnaissance Ar-Ar stepheating data from two feldspar samples, taken from south of Bayi from a 26 Ma granite, and from north of Loulan from an undated granite we suspect is a member of the 20-25 Ma suite. Both feldspars show discordant spectra (Figure 6) and have well defined diffusion data (not shown). Forward modeling of these spectra yields the thermal histories shown on Fig. 6, involving initial rapid cooling, probably upon emplacement at relatively shallow depths, followed by near isothermal stagnation and finally a rapid cooling at ~11 Ma (Bayi) and 6 Ma (Loulan). Given the complexities of exhumation in SE Tibet, it is not possible with only two samples to say very much, but the results from Bayi are consistent with those obtained previously farther west in the Lhasa block.

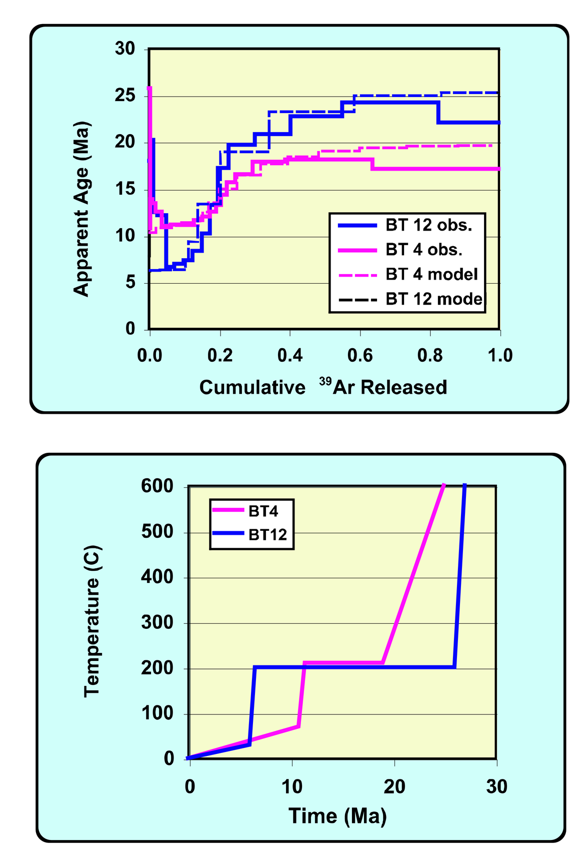


Fig. 6. K-feldspar Ar-Ar stepheating data and thermal history models derived from them.
See map of Fig 3. for sample locations.

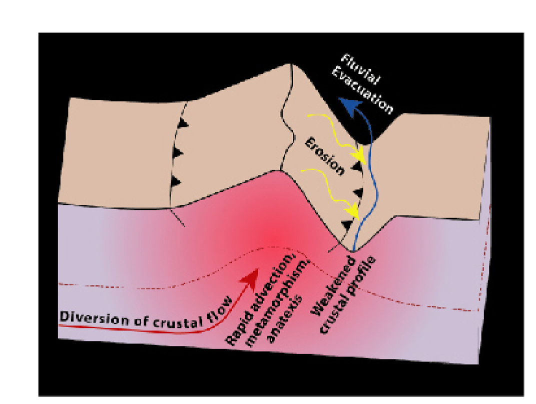


Fig. 10. Model for regional tectonic setting of syntaxial domal uplifts. The western margin of the NB-GP structure would be represented by the thrust fault in the left side of this figure

Seismometer station of the pilot deployment, near Dongjiu, May 2002

Seismology

The seismic component of this project includes a PASSCAL deployment to determine lithospheric architecture, rheology, and fault kinematics, and their relationship to deeper mantle structure. In spring 2002 we conducted a small pilot project to work through field logistics in advance of the main deployment, assess local seismicity, and conduct site characterization studies. We deployed 8 stations, 4 intermediate, and 4 short period, in the Loulan Valley west of the main Namche Barwa metamorphic massif. The region is active seismically as indicated by events recorded by the Chinese Seismological Bureau (Fig 7). In May 2003 we will deploy a 50 station broadband array across southeastern Tibet (Fig. 9). Stations will record local, regional, and teleseismic events over a 12 month period. The regional broadband array will be used to determine crustal and upper mantle structure and dynamics at the plate edge, to develop a more complete model of coupled crustal deformation and mantle flow in the syntaxial region. Nested within the regional array we will deploy a dense 20 element short period array to determine active fault kinematics and crustal structure and rheology beneath the massif (Fig. 8). Data analysis will include tomographic inversions for velocity and attenuation structure beneath the massif and the broader syntaxial region to constrain rheology, receiver-function analysis to determine primary structural boundaries, and earthquake location and focal-mechanism solutions, seismic moment analysis, and determination of shear-wave splitting parameters to look at strain and thermal structure.

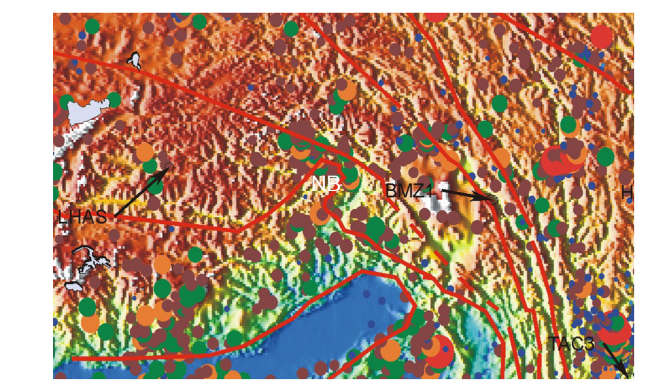


Fig 7. Regional seismic activity from the Chinese Seismological Bureau. NB - Namche Barwa. Red - >M6; orange - M5.4-5.9; green - M4.8-5.3; purple M3-7-4.7; blues - <3.6

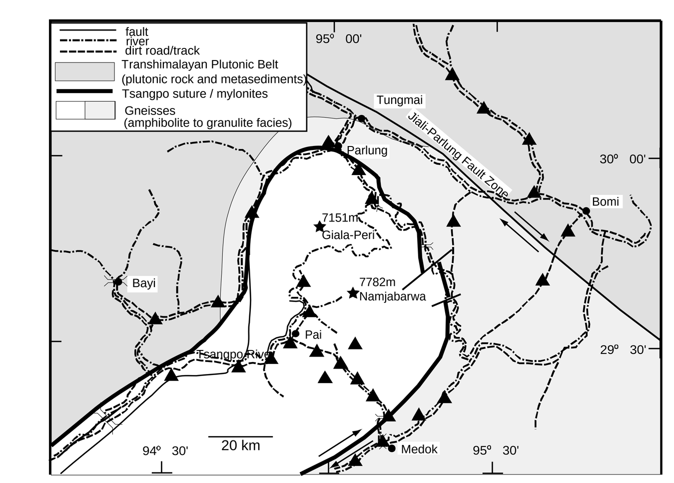


Fig 8.Proposed 20-element local short period array (station locations at triangles) for deployment in May 2003.

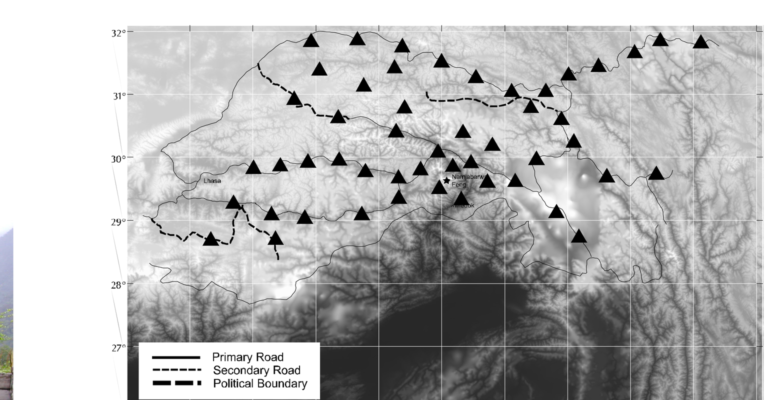


Fig 9. Proposed 50-station broadband seismometer array to be deployed in May 2003.

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