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# Magnetic fabric study in the Triassic slates of the Tethyan Himalaya (SE Tibet)

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**Abstract:** A study of the anisotropy of magnetic susceptibility (AMS) has been done at 24 sites in the Tethyan Himalaya Thrust Belt in SE-Tibet. The sites are located in the Triassic slates. Generally $K_{min}$ axes are well grouped at the pole of the mesoscopic foliation. Magnetic foliation strikes WNW-ESE but shows different dips south and north of the Dalmar fault: it has intermediate dips toward the south in the northern part and intermediate dips to the north in the southern part of the same fault. We present new magnetic fabric data to better understand the tectonometamorphic history of SE-Tibet, a key area to understand the formation history of the Himalaya-Tibetan Plateau uplift.

**Keywords**: AMS, magnetic mineralogy, Tethyan Himalaya Thrust Belt, SE-Tibet.

The study area is located in SE Tibet, west of the Eastern Syntaxis, east of the locality of Zetang, south of Yarlung Tsangpo River and north of the border with Arunachal Pradesh (India). The SE Tibetan area is a key region to understand the tectonic evolution that led to the formation of the Himalayan Belt and Tibetan Plateau. The analyzed rocks are Triassic sediments of the Tethyan Himalayan Thrust Belt, cropping out between the Yarlung Tsangpo Suture (YTS) zone, in the north, and the South Tibetan Detachment System in the south (Fig. 1). It consists of folds and imbricate thrusts involving the whole passive continental margin sequence of the Tethyan Himalaya (Yin and Harrison, 2000). The sampled rocks are mostly slates which experienced a complex tectonic and metamorphic history with two main deformation events both of them related to the development of foliations (S1 and S2) parallel to the axial planes of coeval F1 and F2 fold systems.

In order to characterize the internal structure of the flysch sediments, we applied the method of Anisotropy of Magnetic Susceptibility (AMS), combined with meso and microstructural analyses, to finally relate it to the structural evolution of the area. The analysis of the magnetic fabrics requires knowledge of the major contributions in the bulk magnetic susceptibility in the rocks (Borradaile *et al*., 1986). As we want to correlate the orientation of the three axes of the magnetic ellipsoid with the preferred orienta-

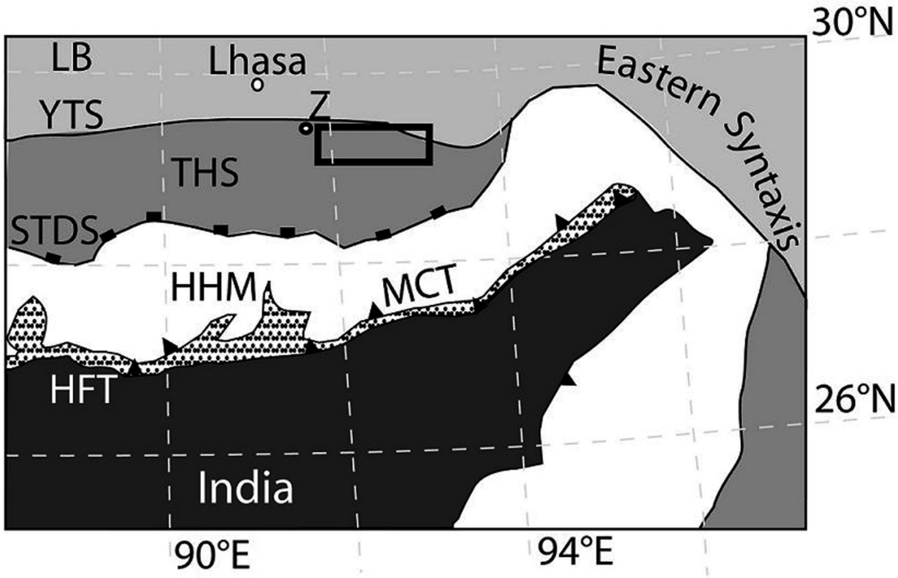


**Figure 1.** Simplified geological map of the East Himalaya and SE-Tibet (modified after Yin and Harrison, 2000). HFT: Himalaya Frontal Thrust; MCT: Main Central Thrust; HHM: High Himalaya Metamorphic rocks; STDS: South Tibetan Detachment System; THS: Tethyan Himalayan Sequences; YTS: Yarlung Tsangpo Suture zone; LB: Lhasa Block; Z: locality of Zetang. The black rectangle indicates the studied area.

tion of phyllosilicates, we must be sure that the bulk susceptibility, or at least its anisotropy, is due to those minerals.

In SE-Tibet where compressional structures dominate (thrust and fold belts) magnetic fabric is usually controlled by cleavage orientation. In particular magnetic foliation becomes parallel to the mesoscopic foliation.

## Methods

A total of 24 sites were drilled with a portable gasoline drill machine, 11 sites to the north of the Darmar Fault and 13 sites to the south. In each site 10 cores were collected. The AMS was measured in 10 standard cylindrical rock samples (specimen 2.5 cm in diameter and 2.1 cm long) per site. AMS measurements were carried out for all specimens with a KLY-2 Kappabridge (Agico). This value of the magnetic susceptibility is the sum of the paramagnetic, diamagnetic and ferromagnetic minerals. AMS measurements give the orientations and magnitudes of the $K_{min}<K_{int}<K_{max}$ axes of the AMS ellipsoid. The relationship between tensors axis, normalized by means of Jelinek´s method was studied using the corrected anisotropy degree $P'$, and the shape parameter $T$ (Jelinek, 1981). Minimum axes of the magnetic ellipsoid were related to the magnetic foliation because the minimum susceptibility axis is nearly perpendicular to the basal cleavage of the mica crystals and nearly parallel to the *c* axis (Borradaile and Werner, 1994). Thus, if the main contribution of our anisotropy of susceptibility is carried by the phylosillicates we can infer the orientation of these crystals by utilizing the AMS.

In order to verify that the main carriers of the anisotropy are paramagnetic minerals, (phylosillicates) one sample per site was analyzed in terms of magnetic mineralogy. An Alternating Gradient Force Magnetometer (AGFM) 2900 (Princeton Measurements Corp.) was used to analyze the hysteresis properties of the samples and the relation between the para and ferromagnetic contributions. Finally, using a pulse magnetometer (Magnetic Measurements MMPM9) specimens were subjected to isothermal remanent magnetization (IRM) in a direct current field until a maximum of 1.8 T, followed by subsequent stepwise thermal demagnetization of the saturation IRM (SIRM). Thermal demagnetization of the SIRM was carried out using an ASC Scientific oven. All the measurements were done in the Paleomagnetic Laboratory of Tübingen University (Germany).

## Results and discussion

The hysteresis loops point out that the main carriers of the anisotropy of the magnetic susceptibility are paramagnetic minerals. However, the quick saturation of the IRM (near-saturation at 0.3 T-0.5 T) and decays of thermal demagnetization of the SIRM around 325 °C and 580 °C indicates the presence of ferromagnetic minerals pyrrhotite and magnetite respectively.

The mean intensity of the AMS for the slates is 425.6 (standard deviation, STD=422) ($\times 10^{-6}$ SI). The $P'$ values are high ($P'_{mean}$=1.38 (STD=0.33)) suggesting a

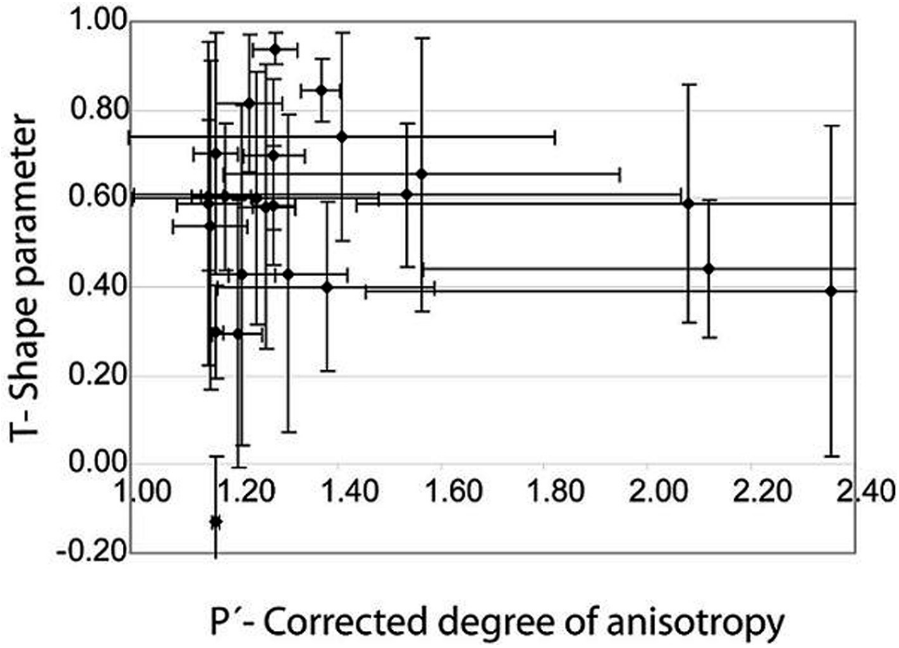


**Figure 2.** $P'$-$T$ diagram for the 24 studied sites.

strong degree of mineral alignment. The $T$ parameter ($T_{mean}$=0.55 (STD=0.21)) is typical of oblate ellipsoids; only in the site QU20 $T$ is negative, indicating a prolate ellipsoid (Fig. 2).

General distribution in equal area projection for $K_{max}$, $K_{int}$ and $K_{min}$ shows a cluster to girdle distribution of $K_{max}$ and $K_{int}$-$K_{min}$ present good grouping that coincide with the pole of the mesoscopic foliation measured in the field.

Magnetic Foliations are calculated from the plane perpendicular to the mean vector (Jelinek, 1978) of $K_{min}$. These trajectories present WNW-ESE strike parallel to the strike of the main faults. Dips of magnetic foliation can be divided into two domains. In the north

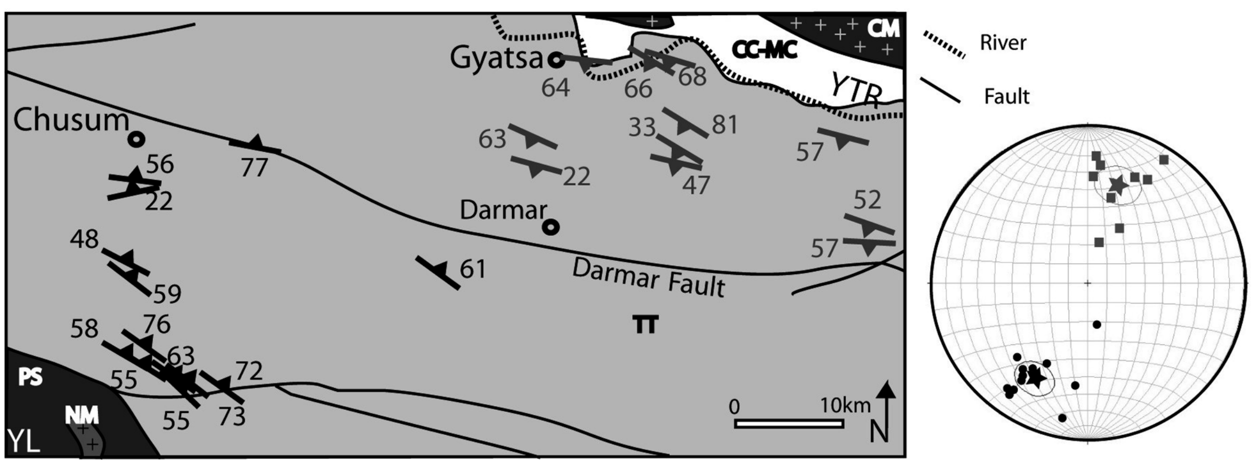


**Figure 3.** Map of Magnetic foliations within a simplified geological map of the studied area (modified from China Geological Survey, 2004) and equal area projection of the $K_{min}$ means per site. In the equal area plot, the circles refer to $K_{min}$ of the southern area, the squares are $K_{min}$ of the northern area and the stars are the mean vectors. Map key: YL: Yala-Xiangbo leucogranite; NM: Neogene Magmatic rocks; PS: Paleozoic Schist; TT: Triassic turbiditic slates, phyllites and sandstones; CC-MC: Cretaceous Clastic rocks and Melange Complex; CM: Cretaceous Magmatic rocks-Gangdese granitoids; YTR: Yarlung-Tsangpo River. The Darmar fault appears in the Chinese geological map without name, but we named it Darmar Fault because of its proximity to the town of Darmar.

of the Dalmar Fault the magnetic foliation dips towards the south, whereas in the southern part the magnetic foliation indicates intermediate dips towards the north (Fig. 3).

The $K_{min}$ for the whole area are distributed in two clusters; in the southern part $K_{min}$ has a trend of 209.1°, and plunge of 30.7°, whereas in the northern part $K_{min}$ has a trend of 017.3° and plunge of 34.7° (Fig. 3).

In the southern part of the Darmar Fault the main mesoscopic foliation is S1 and it is parallel to the magnetic foliation. S1 dips to the north and is parallel to the thrust plane that separates the Paleozoic Schists of the Yala Xiangbo dome from the Triassic flysch. In the northern area S2 becomes more dominant than S1 close to the YTS, and the magnetic foliation is parallel to the main mesoscopic foliation. The trends of the magnetic foliations are concordant with the structural position of the study rocks in the hanging wall of the Renbu-Zedong Thrust (Harrison *et al.*, 2000). Dips towards the south match with the overlapping of the passive continental margin sediments of the northern Indian margin over the mélange complex (Harrison *et al.*, 2000).

## Conclusions

According to the rock magnetic data, paramagnetic silicates mainly control the magnetic foliation of the Triassic slates. Nevertheless IRM and thermal demagnetization of SIRM shows the presence of pyrrhotite and magnetite as the main ferromagnetic minerals.

The magnetic fabric is oblate; $K_{min}$ presents a good grouping that coincides with the pole of the mesoscopic foliation. The corrected degree of the anisotropy of magnetic susceptibility is high, indicating a strong orientation of the paramagnetic minerals. The studied area can be divided in two domains depending on the results of the magnetic foliation. The northern area present magnetic foliations dipping to the south probably related with its position in the hanging wall of the east continuation of the Renbu-Zedong Thrust.

More AMS analysis in the slates and in the diorite dykes are going on in the studied area. Also illite crystallinity analysis, vitrinite reflectance and K/Ar dating are running parallel to the magnetic measurements to clarify the tectonometamorphic history of the area. This information will provide more insights to better interpret the paleomagnetism study that is also under investigation.

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