EGU General Assembly 2022

IISER KOLKATA

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# Preliminary fracture analysis from the frontal most exposure of a major roof thrust in the Eastern Himalaya: Insights from the Ramgarh thrust, Sikkim Himalaya

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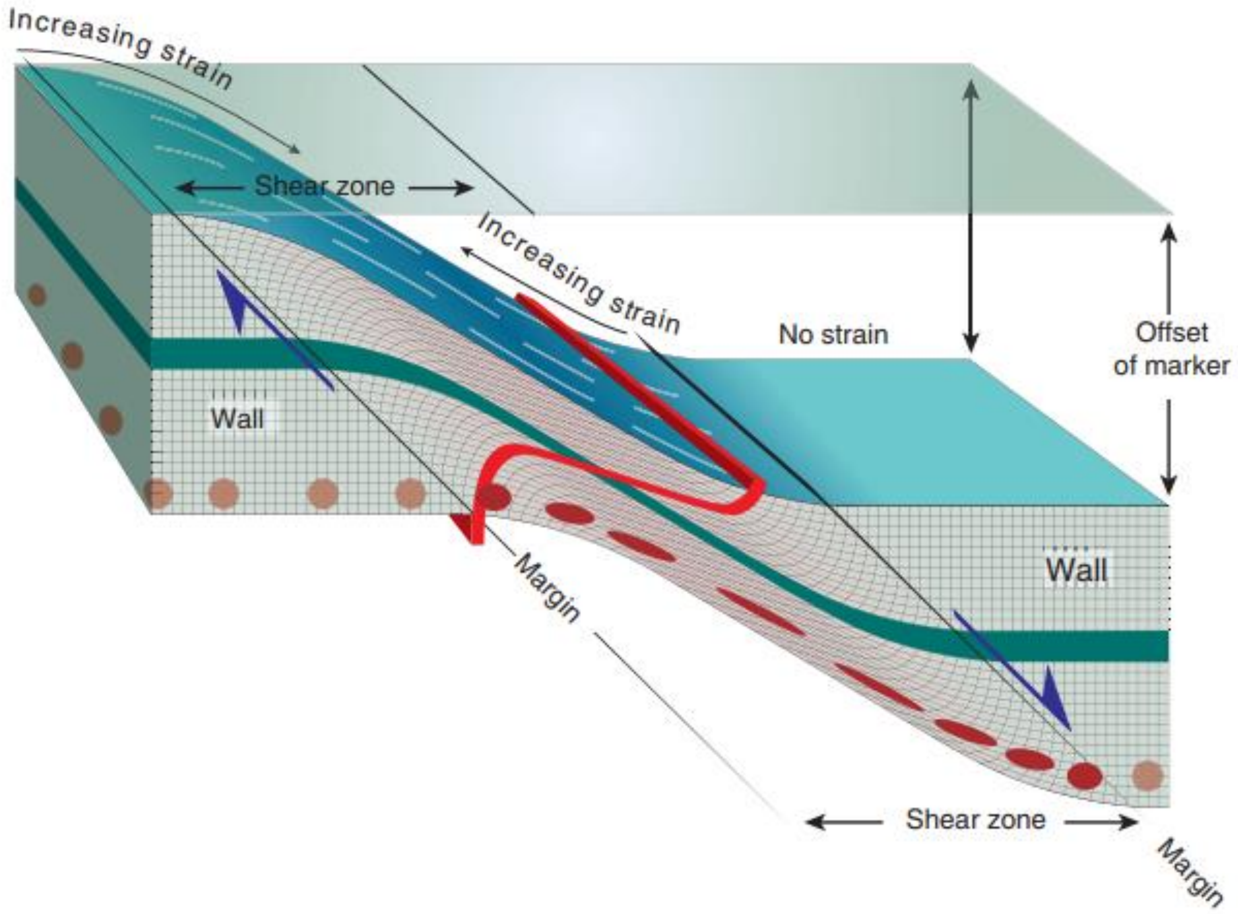
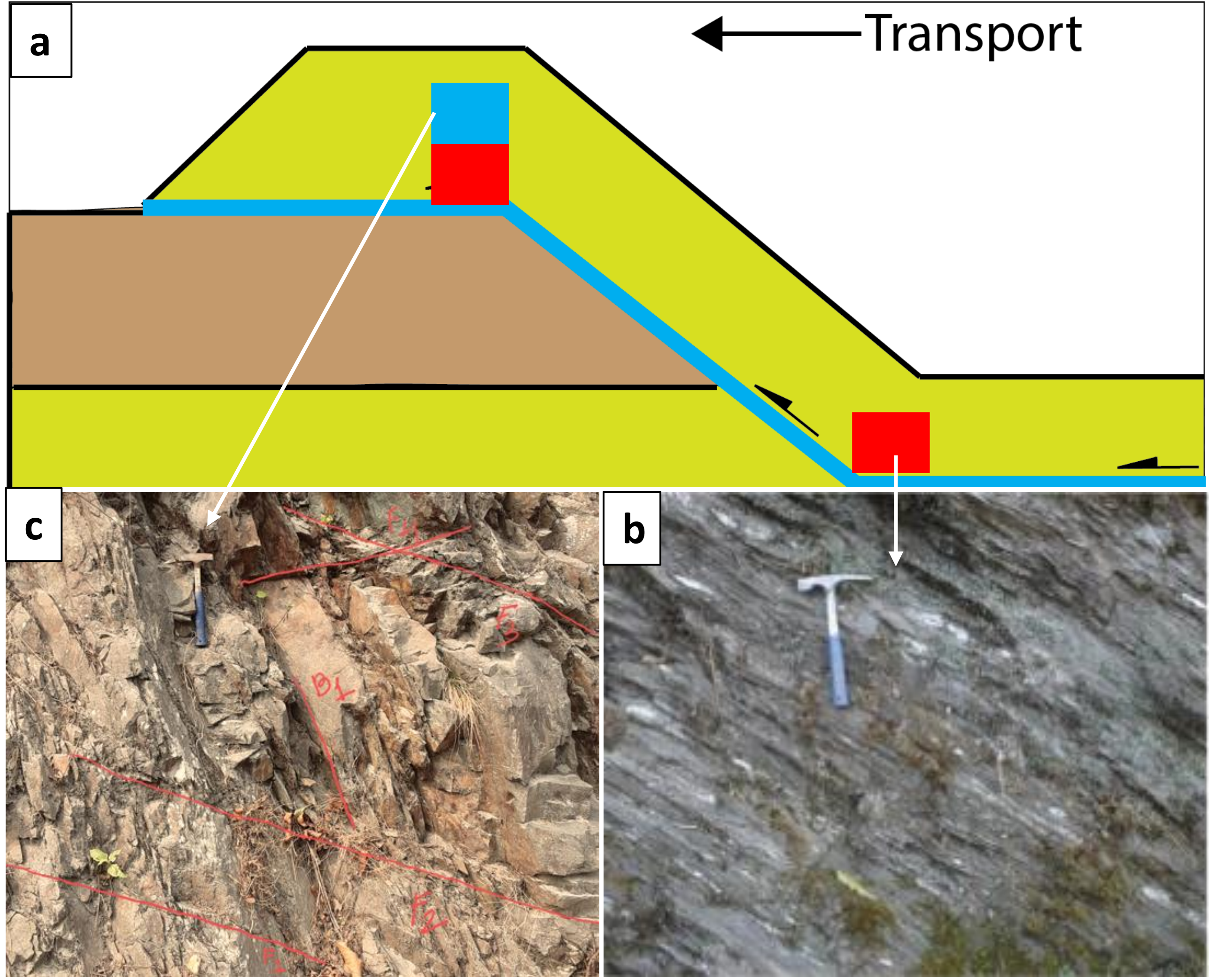
# BACKGROUND

Shear zones are discrete zones of localized deformation.

*Representation of an ideal shear zone (Fossen, 2016)*




**In this study, we investigate the deformation signatures related to the shallow crustal conditions of a major thrust from an active fold thrust belt.**



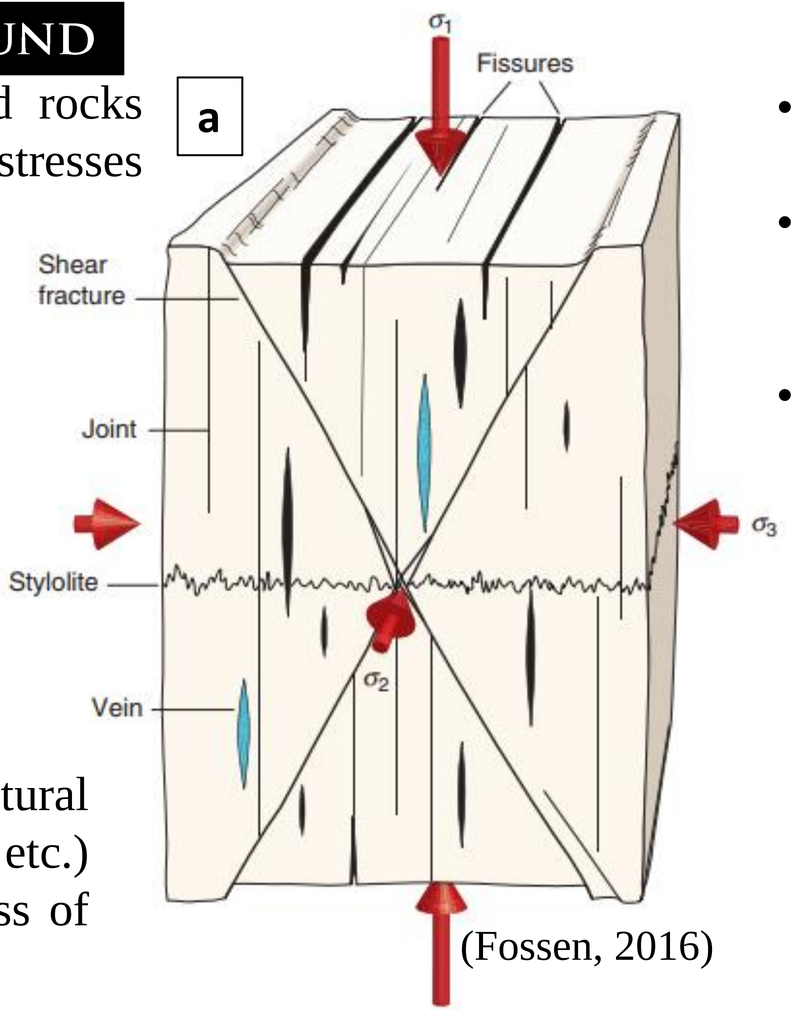

When thrust faults cut up-section, shear zone rocks record overprinting of plastic with quasi-frictional deformation structures.

*(a) Cartoon showing progressive thrusting and overprinting of deep crustal with shallow crustal deformation structures (b) Shear zone rocks recording plastic deformation- Mylonites (c) Shear zone showing quasi-frictional deformation structures*

# Background

Fracture orientations within deformed rocks relate to the orientation of principal stresses during their formation (Fig. a)


Fracture formation has both structural (position within the fold, overburden etc.) and lithological (composition, thickness of mechanical units etc.) controls (Fig. b)



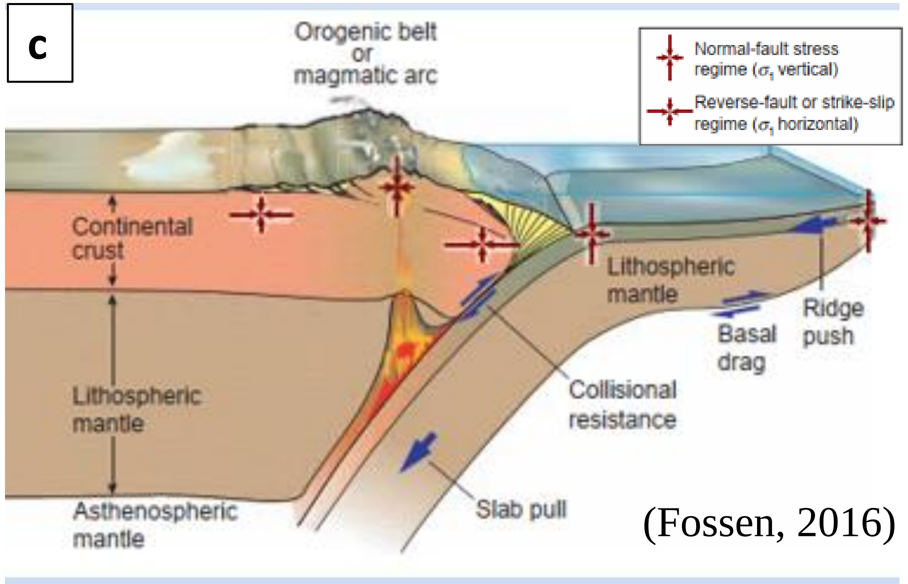

(Fossen, 2016)

**Objectives:**

- Identification and characterization of fracture systems from a major shear zone of an active fold thrust belt (FTB).
- To understand how fracture attributes vary with structural distance and mechanical anisotropy within a major shear zone.
- Estimation of paleostress using mesoscopic brittle structures from the shear zone and thereby compare local stress with far-field stress.

# Implications

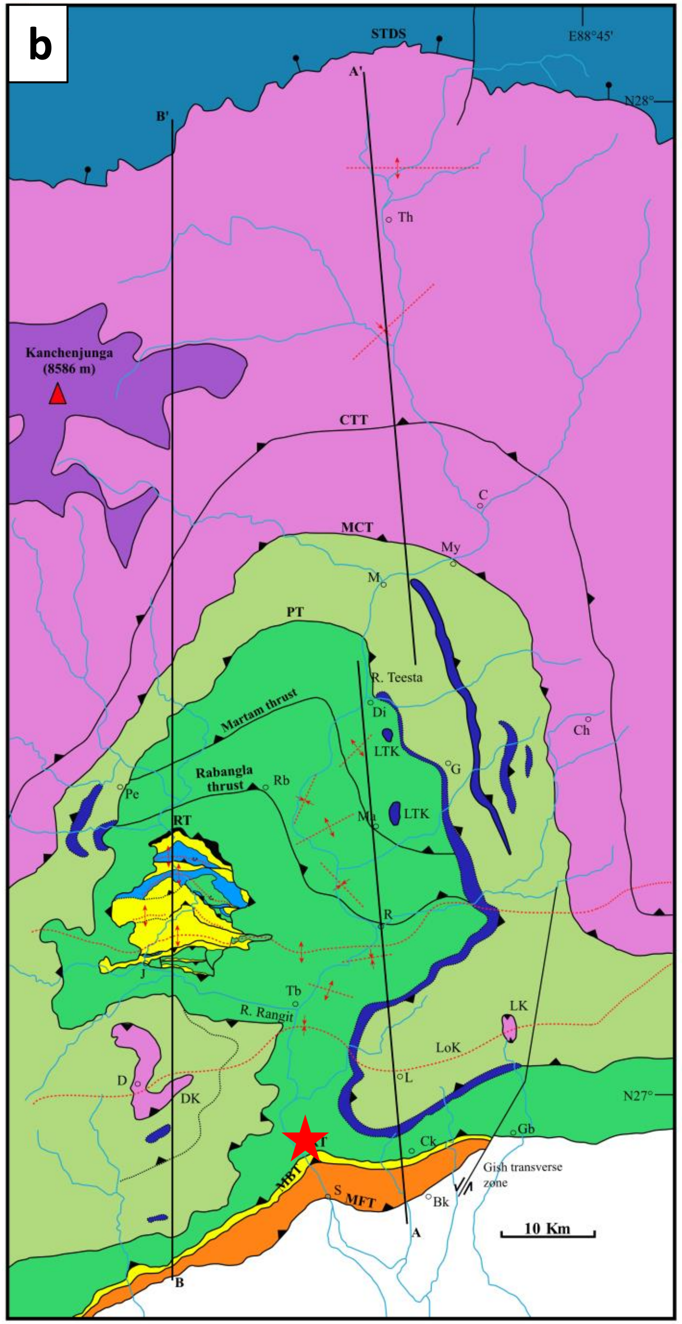
- Help identify the factors that affect fracture formation and propagation.
- Give insights into the local stress orientations during shallow crustal deformation of a major shear zone.
- Give insights into how local stress compare with regional stress.



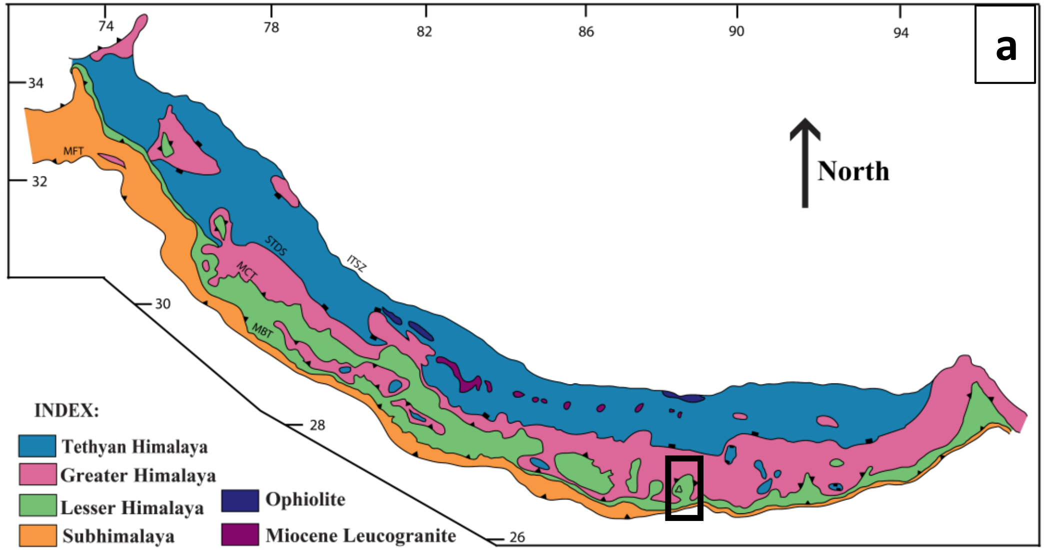

(Fossen, 2016)

*(a) Orientation of various fracture types with respect to the principal stresses (b) Cataclastic deformation bands in sandstone that fade away in underlying fine grained unit( c) Representation of convergent boundary setting with convergence related regional stress orientations*

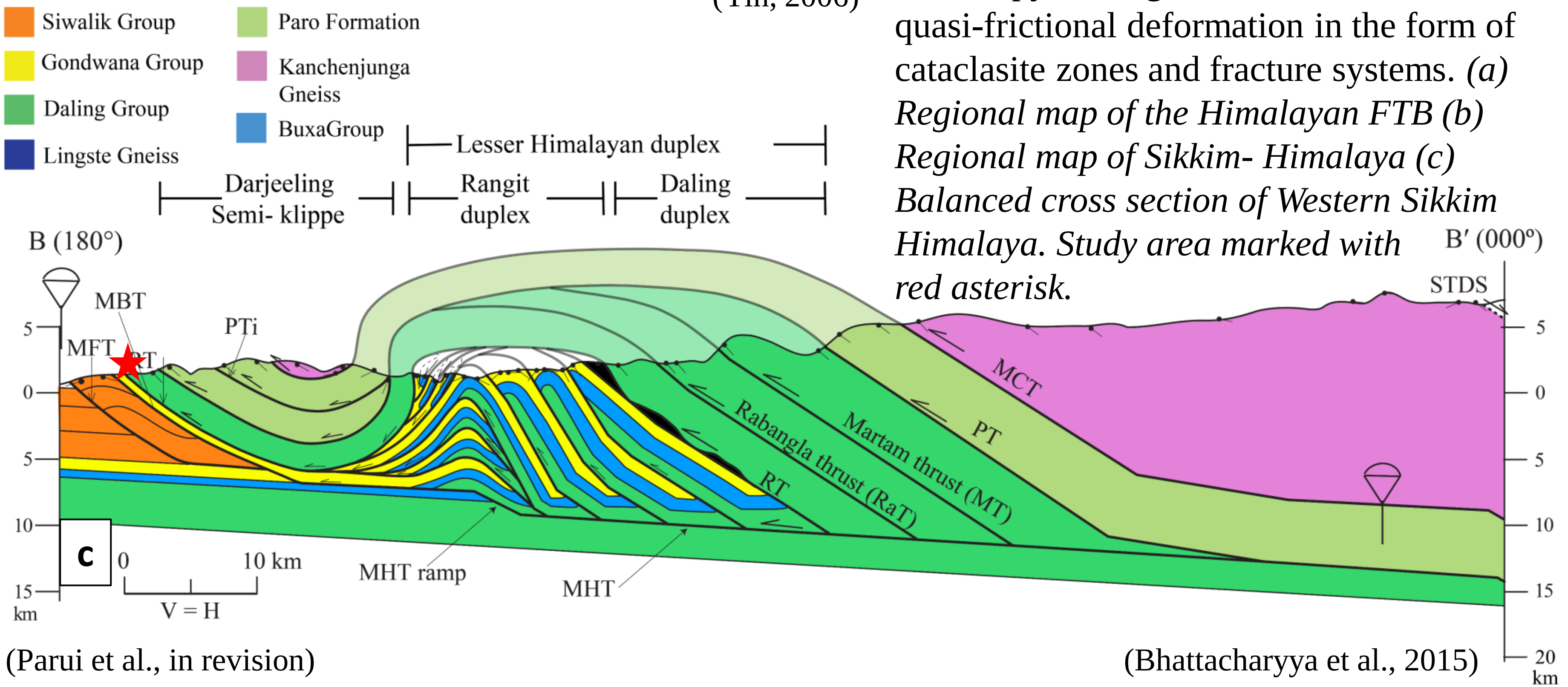
# Study Area




(Parui et al., in revision)




(Yin, 2006)




(Bhattacharyya et al., 2015)

Ramgarh thrust (RT) is an intermediate crustal thrust of the Sikkim Himalayan fold thrust belt that has recorded a translation of ~58-65 km. RT has emplaced from a minimum depth of ~12 km and hence records overprinting of deformation structures. RT acts as the roof thrust of Lesser Himalayan duplex, hence got reactivated several times, and records a long deformation history. RT carries Daling quartzites and phyllites in the hanging wall, therefore exhibits mechanical anisotropy. Daling rocks show evidence of quasi-frictional deformation in the form of cataclasite zones and fracture systems. *(a) Regional map of the Himalayan FTB (b) Regional map of Sikkim- Himalaya (c) Balanced cross section of Western Sikkim Himalaya. Study area marked with red asterisk.*

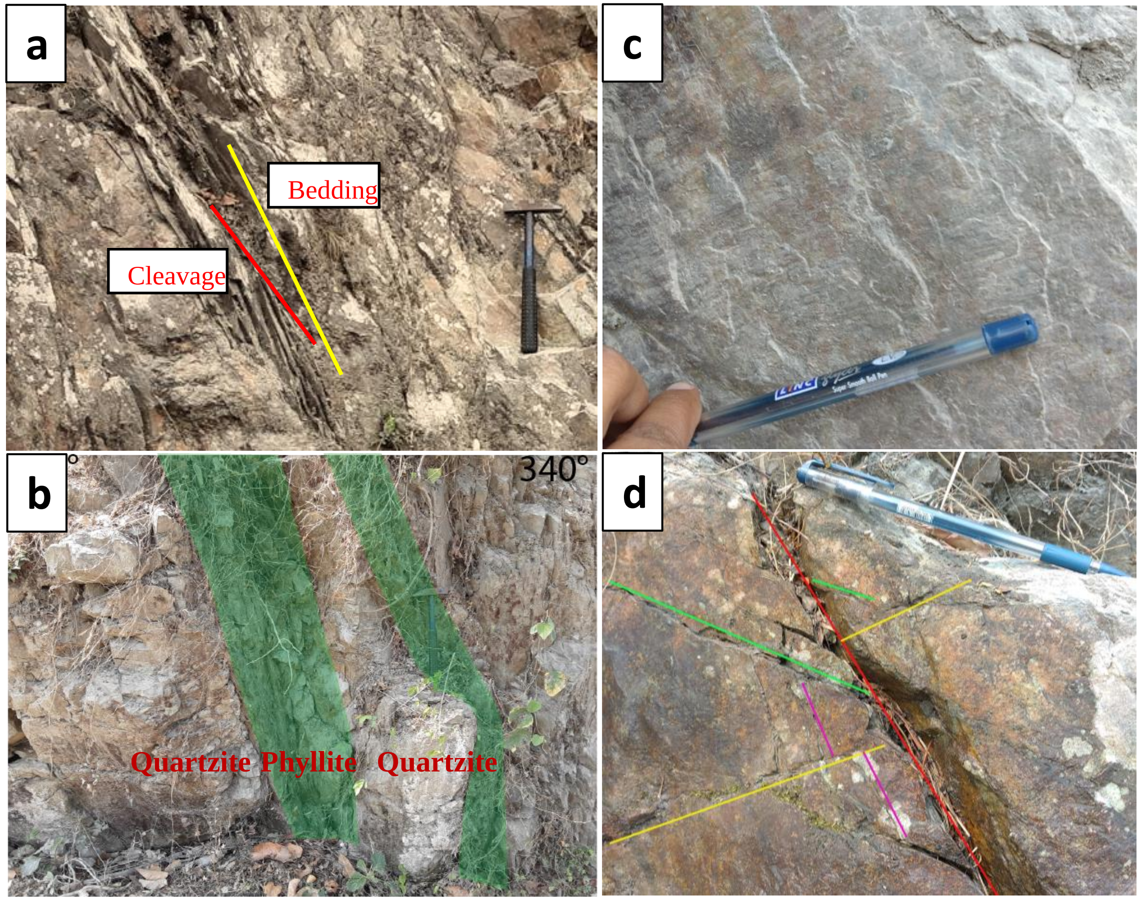
# Methods

## Field analysis

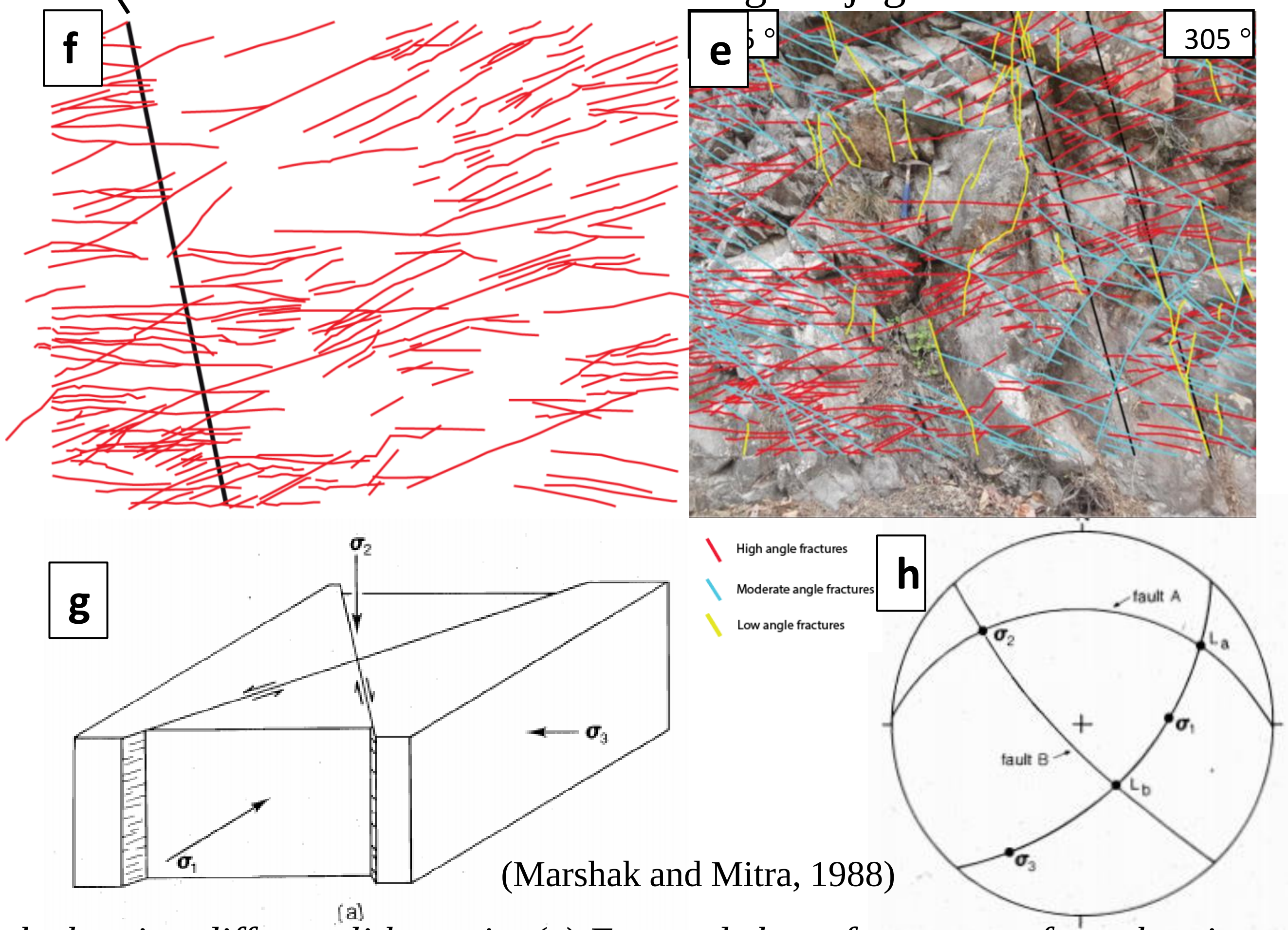
- Collection of structural data
- Estimating thickness and composition of beds
- Fracture characterization in the field
- Establishing temporal relationships between fracture sets

## Lab analysis

- Fracture characterization with respect to bedding
- Analysing fractures to test the effect of structural distance, lithology and thickness of beds
- Paleostress estimation using conjugate shear fractures.



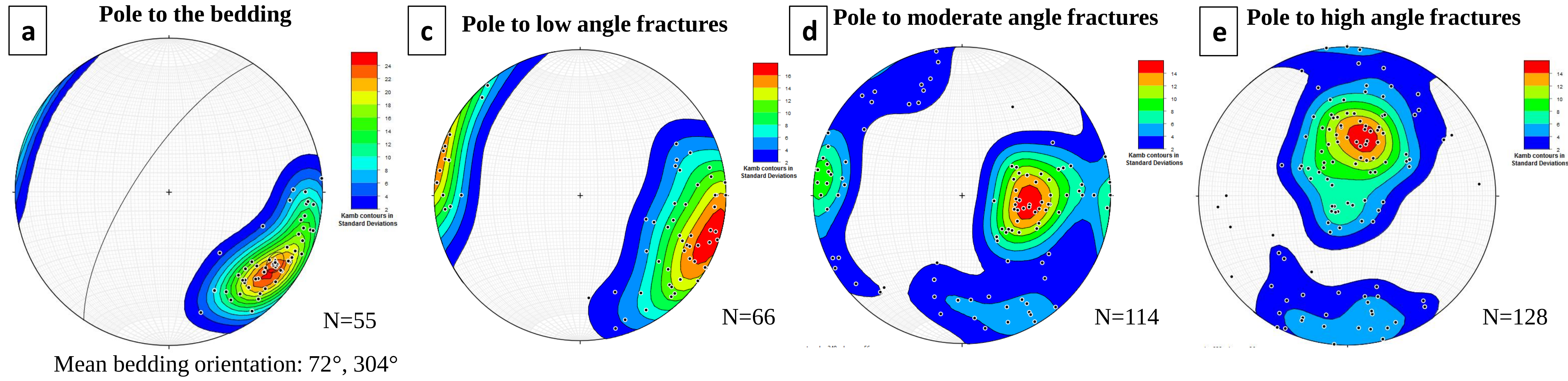

Scanline

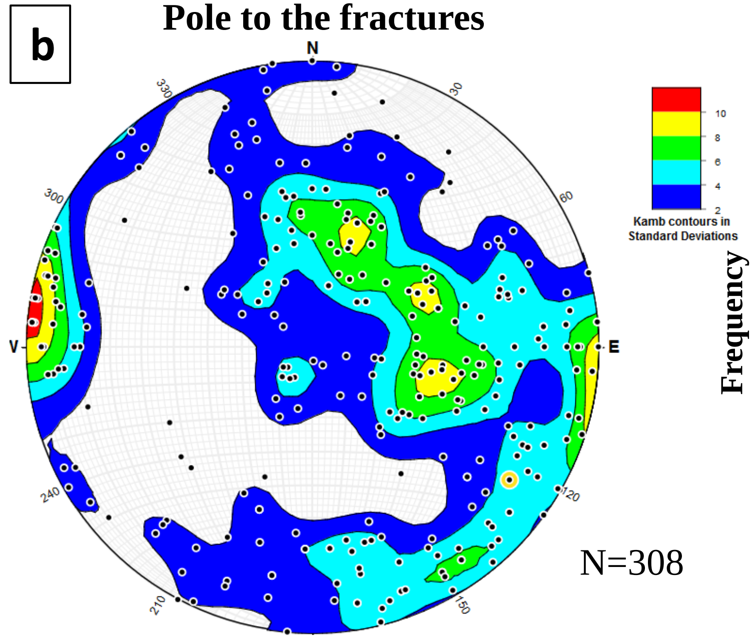


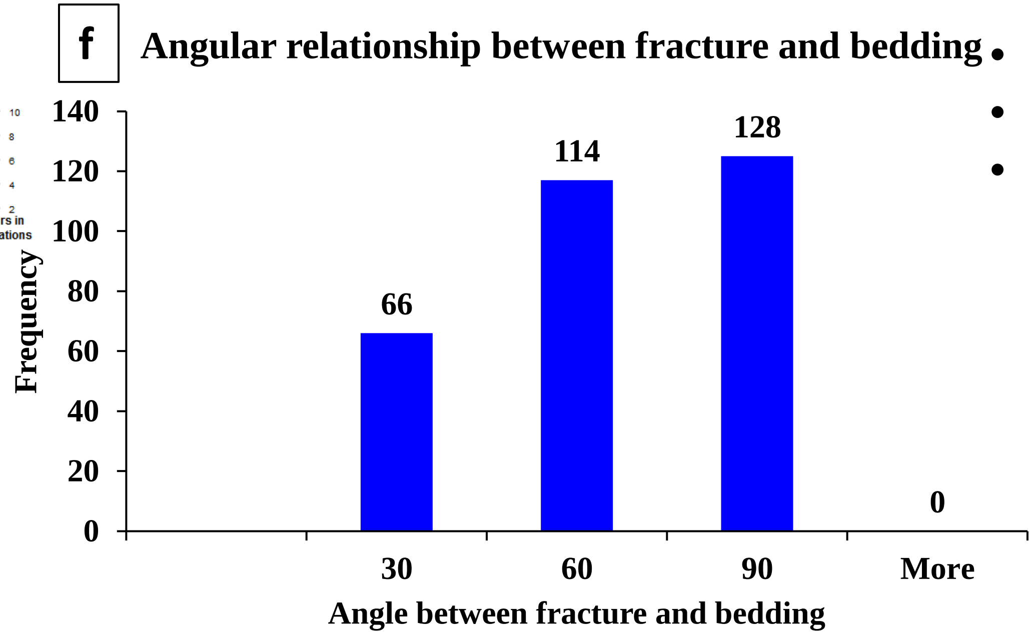

(Marshak and Mitra, 1988)

*(a) Photograph showing bedding- cleavage relationship (b) Photograph showing different litho-units (c) Exposed shear fracture surface showing slickenlines and slickensteps (d) Crosscutting relation between fractures (e) Fracture characterization with respect to bedding. Different fracture sets marked in different colours (f) Scanline constructed for the high angle fracture intensity analysis (g) Orientation of principal stress axes with respect to conjugate shear fractures (h) Stereographic projection of conjugate shear fractures and principal stress axes*

# RESULTS | FRACTURE CHARACTERIZATION WITH RESPECT TO BEDDING



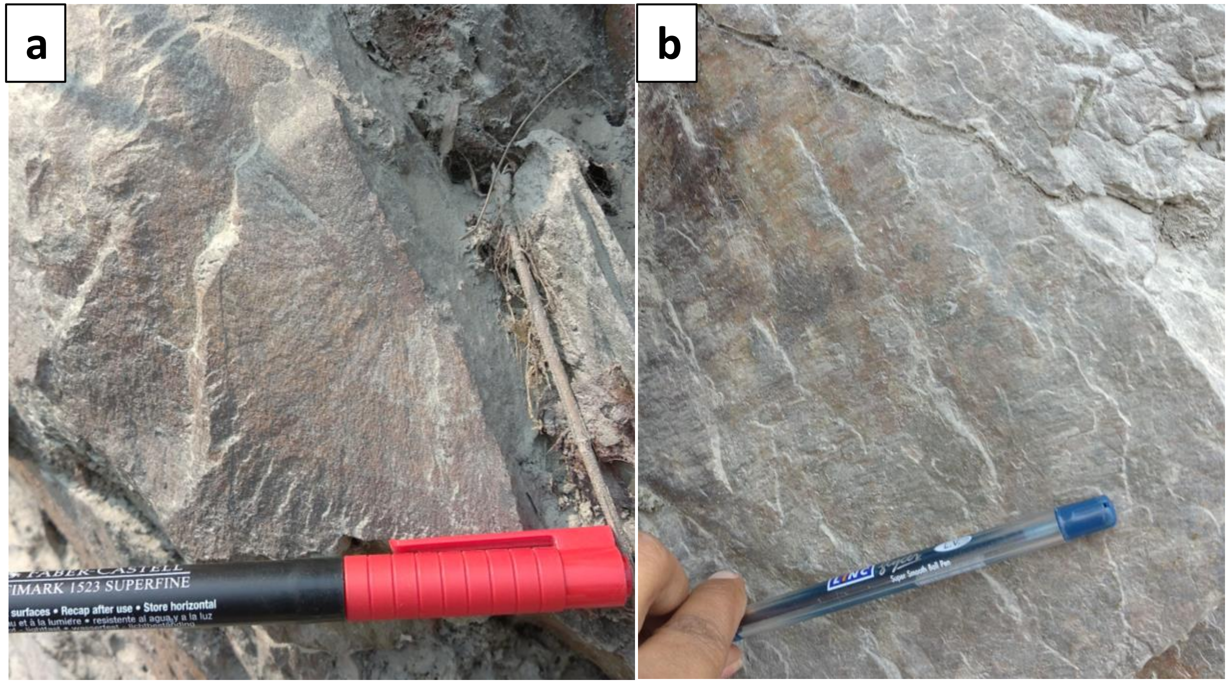




- The mean bedding is oriented 72°, 304°
- Fractures are randomly oriented
- Dominance of high-angle fractures (~41%) followed by moderate-angle (~37%) and low-angle fractures (~21%)

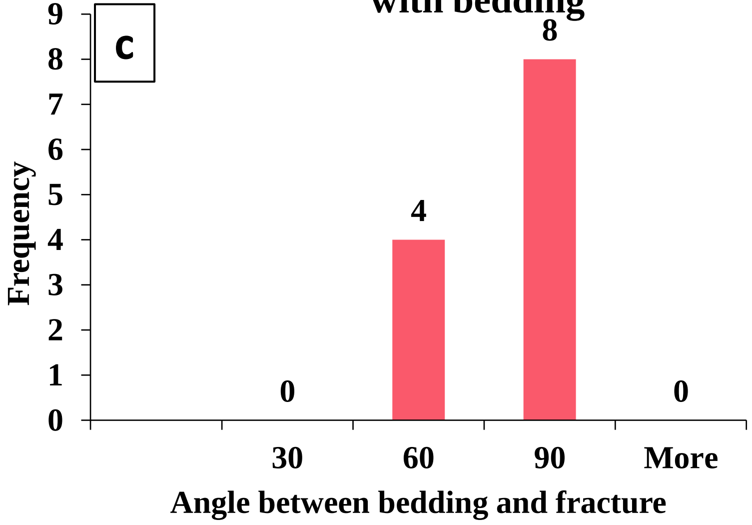
*Equal area lower hemisphere projections (a) Pole to the bedding (b) Pole to the fractures (c)Pole to low-angle fractures (d) Pole to moderate-angle fractures (e) Pole to high-angle fractures (f) Frequency plot of angle between fracture and bedding*

# Results | Fracture characterization based on the mode of opening | Temporal relationship between fractures

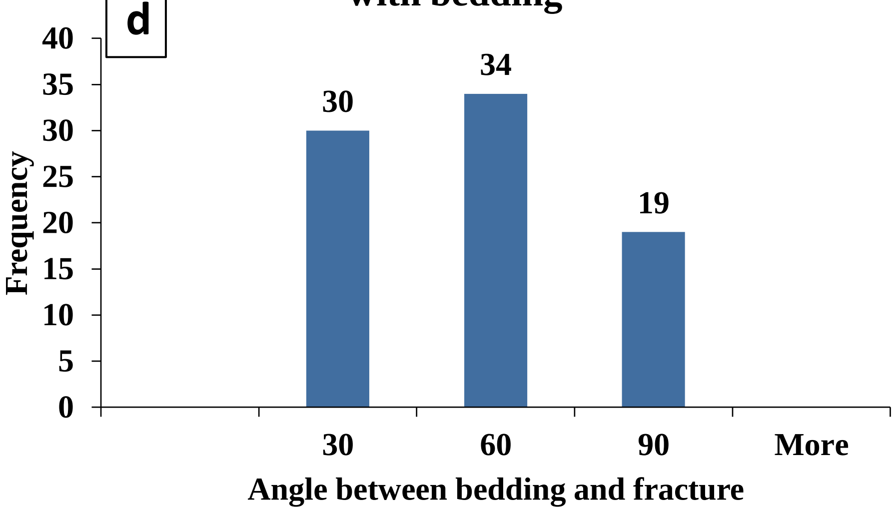



*(a) Plumose structure (b) Shear fracture plane showing slickenlines and slickensteps (c) Frequency plot of angle between bedding and extension fractures (d) Frequency plot of angle between bedding and shear fractures (e) Cross-cutting relation between fractures.*


**Angular relationship of extension fractures with bedding**

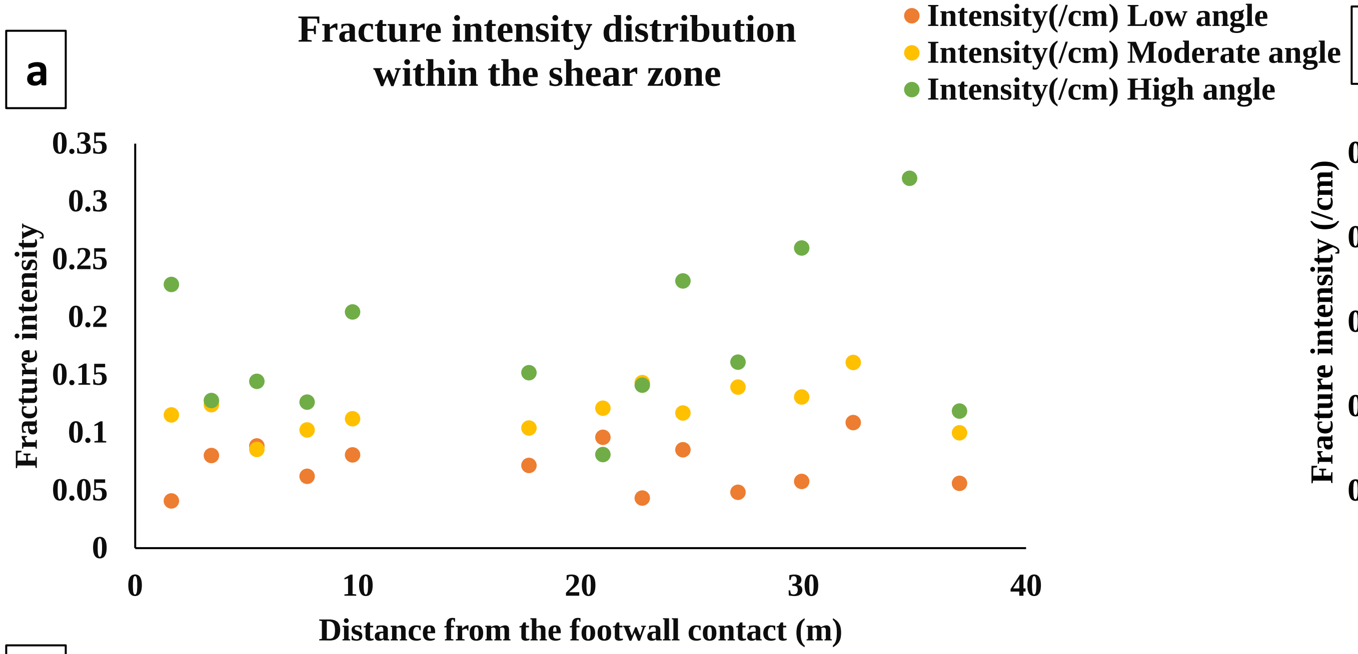


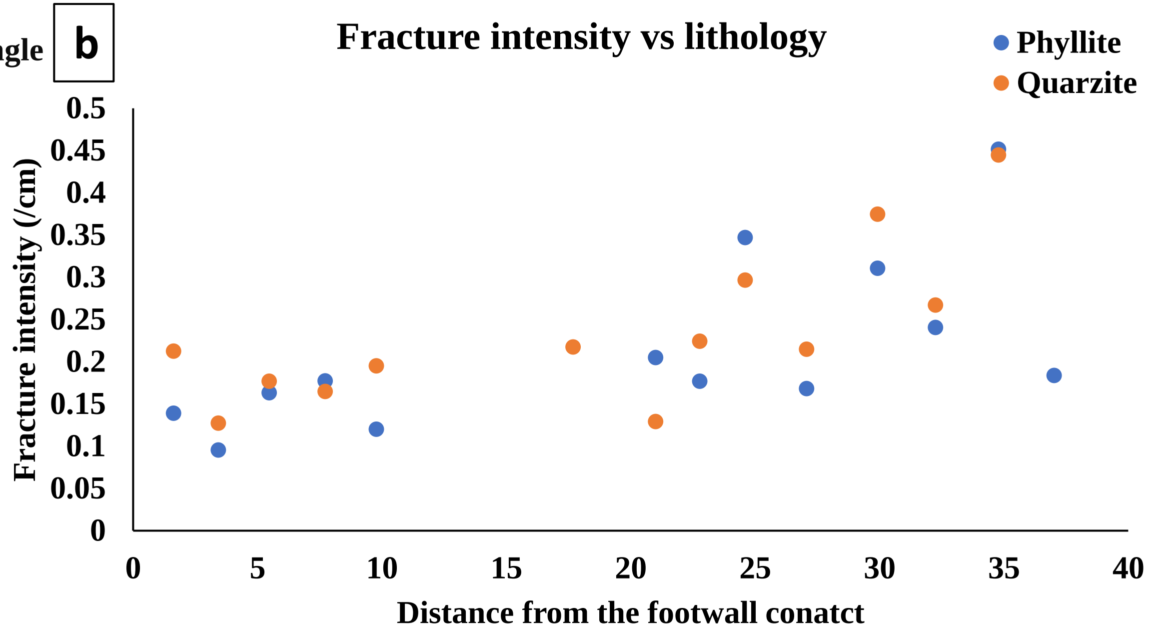

**Angular relationship of shear fractures with bedding**

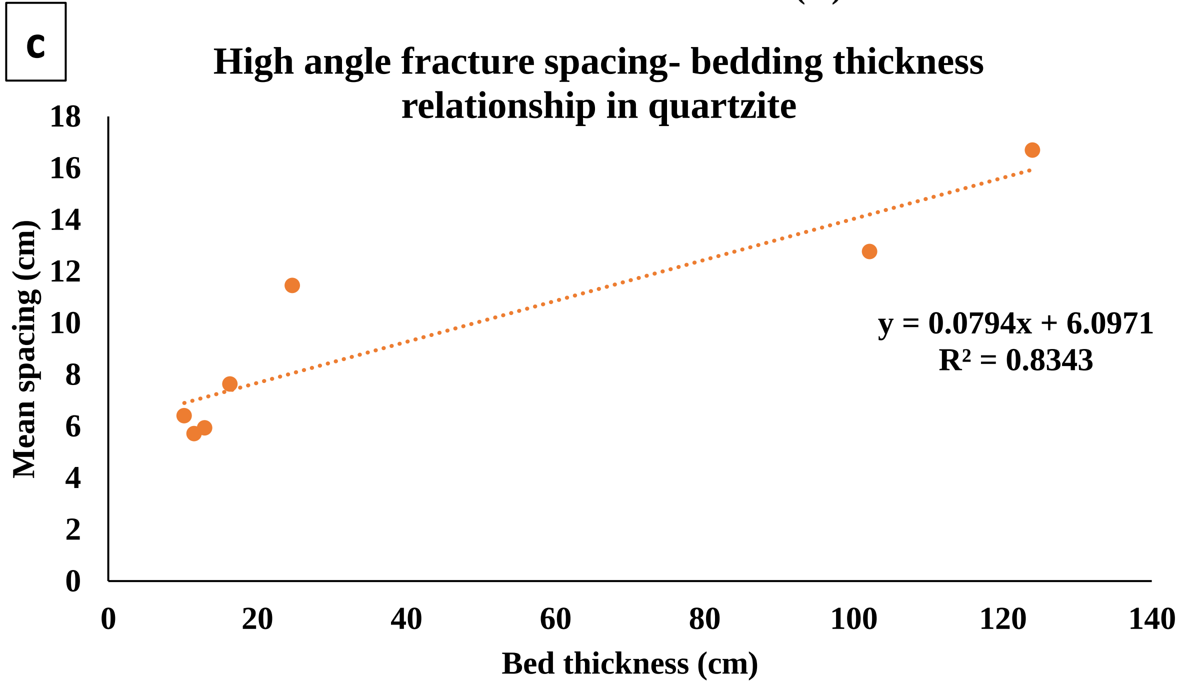



- Dominance of high-angle extension fractures (66.66 %).
- Dominance of low-angle (36.14 %) and moderate-angle (40.9 %) shear fractures.
- Low-angle fractures formed first, followed by moderate-angle and high-angle fractures.

# RESULTS | FRACTURE ATTRIBUTE STUDY



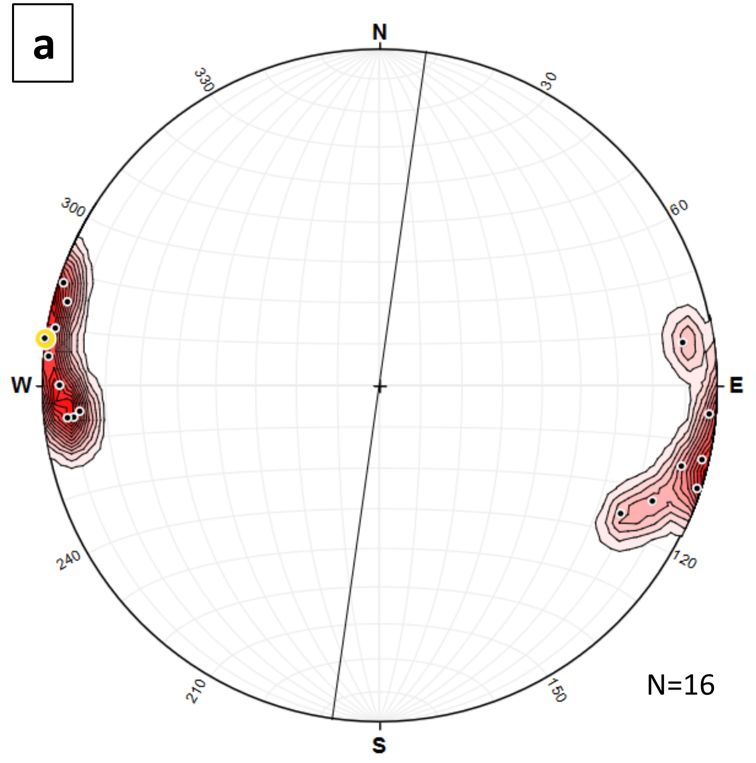




- High-angle fractures have the highest fracture intensity followed by moderate-angle and low-angle fractures.
- Quartzites record higher fracture intensity compared to phyllites.
- High-angle fractures in quartzites show a linear mean fracture spacing (S)- bed thickness (T) relationship.
- S/T values range from ~0.1 to 0.6.

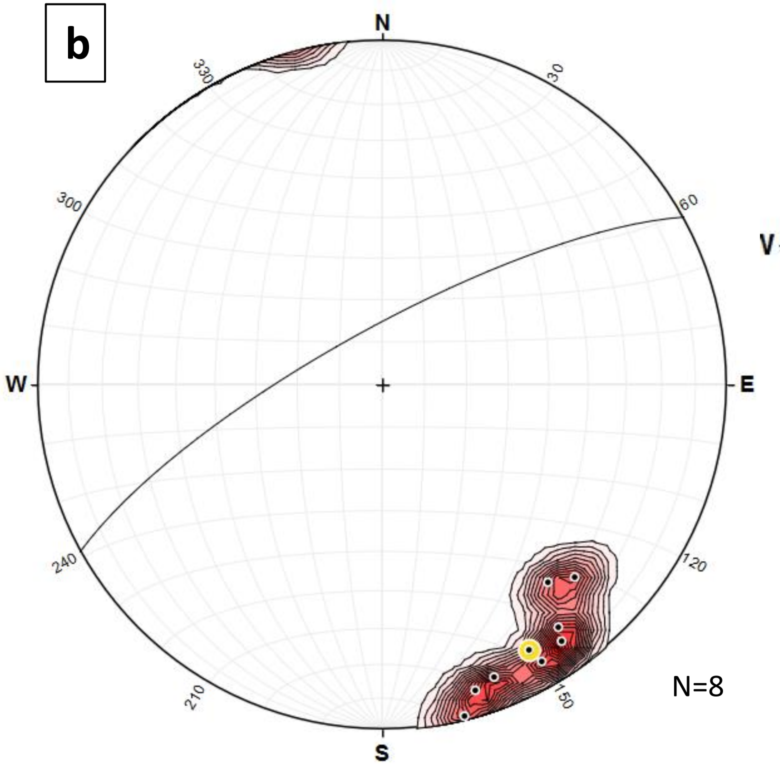
*(a) Plot of fracture intensity distribution within the shear zone (b) Plot of fracture intensity with respect to lithology (c) Plot of mean fracture spacing with respect to thickness of beds.*

# RESULTS | PALEOSTRESS RECONSTRUCTION USING CONJUGATE SHEAR FRACTURES

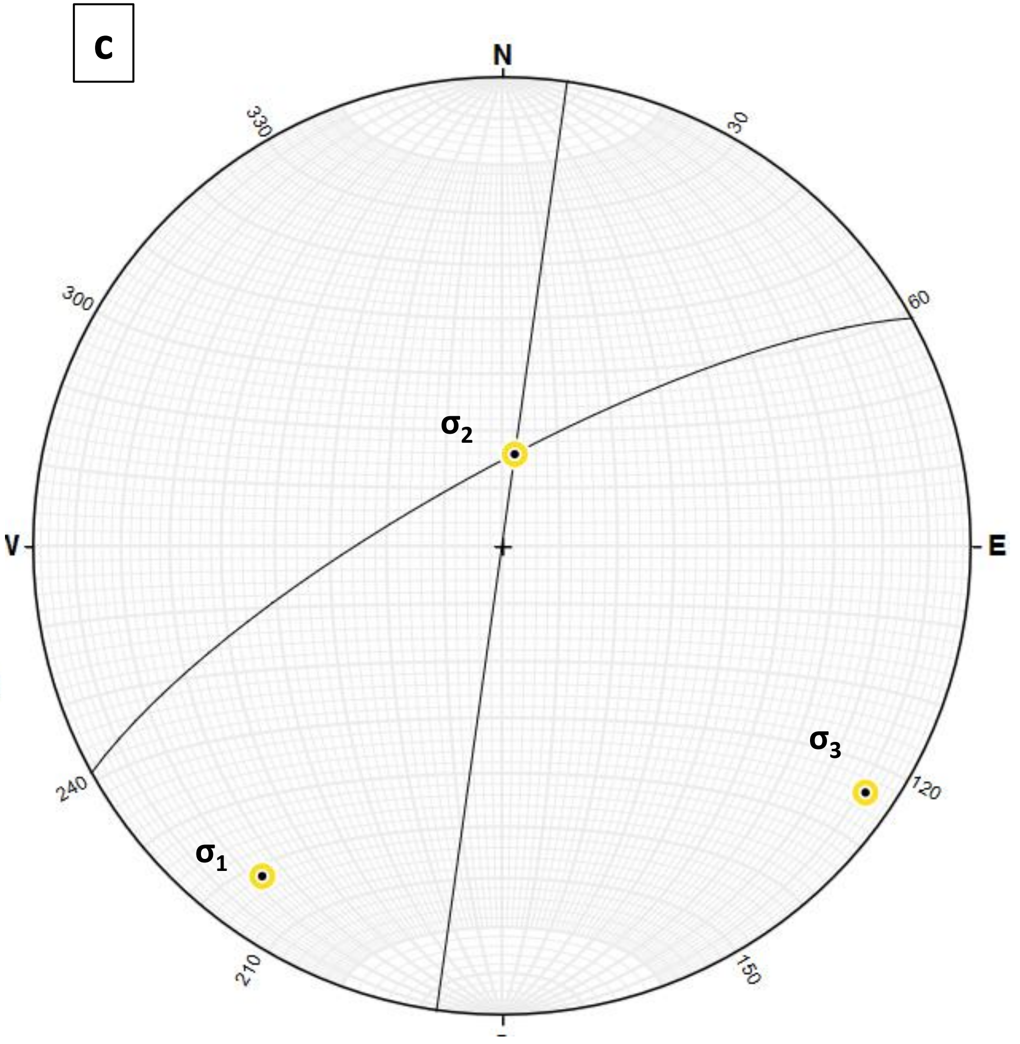
- Dihedral angle between the mean shear fracture clusters ~54º.
- Cluster #1 and Cluster #2 are oriented ~ 27° and ~ 32° to the mean bedding, respectively.
- The local maximum principal stress ($\sigma_1$) is oriented sub-horizontally with a SSW trend (14°, 216).




Cluster #1
Mean orientation: 90°, 098




Cluster #2
Mean orientation: 77°, 331




*Equal area, lower-hemisphere projections (a) Shear fracture cluster 1 (b) Shear fracture cluster 2 (c) Orientation of principal axes $\sigma_1$, $\sigma_2$ and $\sigma_3$.*

# Conclusions

- High-angle fractures (~41%) are the dominant population in the RT shear zone followed by moderate-angle (~37%) and low-angle fractures (~21%).
- Shear and extension fractures show different distributions with respect to bedding.
- Low-angle fracture set formed first followed by moderate-angle and high-angle fractures.
- High-angle fractures have the highest fracture intensity followed by moderate-angle and low-angle fractures.
- Competent units (Quartzites) record higher fracture intensity than incompetent units (Phyllites). This observation is in agreement with the existing literature which reports that higher fracture intensities occur for stronger rocks (Ericsson et al., 1998; Nelson, 2001).
- Fracture lengths are constrained by cross cutting of fractures and mechanical anisotropy. Lithological boundaries act as crack stopping mechanical discontinuities which prevent fracture propagation.
- Ratio of fracture spacing to thickness of beds (S/T) range ~0.1-0.6. Such closely spaced fractures can be formed due to the effect of overburden (Bai and Pollard, 2000).
- The local maximum principal stress ($\sigma_1$) is oriented sub-horizontally with a SSW trend (14°, 216). This estimate is in agreement with the current global stress orientations from the Eastern Himalaya, where $\sigma_1$ is near horizontal and trends NNE – SSW (Larson et al., 1999).

# References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