Structural Mapping and Analysis of Cross-cutting Relationships Between Geologic Structures at Doi Suthep, Chiang Mai Province

Ittipon Pusing
Department of Geology, Faculty of Science, Chiang Mai University

Abstract

This study examines brittle deformation and fracture-set development within a 5 × 5 km litho-structural mapping area surrounding Pha Ngoep Waterfall, Doi Suthep, Chiang Mai, northern Thailand. Mapping distinguished rock units by lithology and deformation intensity, including mylonite at Pha Ngoep, aplite at the Viewpoint outcrop, and deformed granite at surrounding sites, and documented the distribution of joints, faults, and slip surfaces. Structural data were collected from systematic outcrop measurements, scanline fracture sampling, and photo documentation. Joint orientations were analyzed using rose diagrams and stereographic projections; contoured stereonets were used to assess clustering and orientation variability. Fault-slip kinematics were evaluated using FaultKin-type analyses and integrated with the litho-structural map. Relative chronology between major joint sets was constrained from cross-cutting and abutting relationships. Results identify two principal brittle trends (N–S and NNW–SSE) that vary across the study area, supporting multi-stage brittle deformation with localized reactivation. These patterns are linked to evolving stress conditions during Chiang Mai Basin development and subsequent deformation.

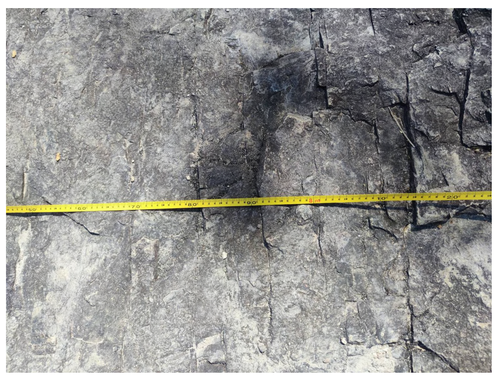
Introduction



Cenozoic extension in northern Thailand shaped the Chiang Mai Basin and exposed high-grade basement in the Doi Suthep domain, but geological maps around Pha Ngoep often oversimplify crystalline rocks and deformation fabrics. This study maps a 5 × 5 km area around Pha Ngoep Waterfall and distinguishes mylonite, aplite, and deformed granite to document joints, faults, and slip surfaces. Joint sets are summarized with rose diagrams and stereonets, fault-slip kinematics are evaluated from slickenlines using FaultKin-type analysis, and cross-cutting/abutting relationships constrain relative chronology to link local brittle deformation to regional basin-related tectonics.

Method

1.Field mapping and data acquisition



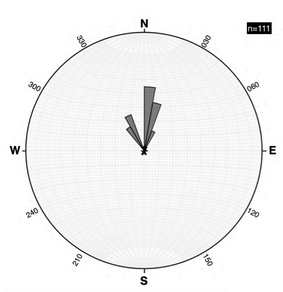
- Conducted a 5 × 5 km geological mapping around Pha Ngoep.
- Classified rock units based on lithology and deformation intensity (mylonite, aplite, deformed granite).
- Used scanline-based sampling to measure joint orientations and geometric properties.
- Documented fault-slip data (slickenlines) and cross-cutting/abutting relationships to constrain relative chronology.

2.Data processing and interpretation

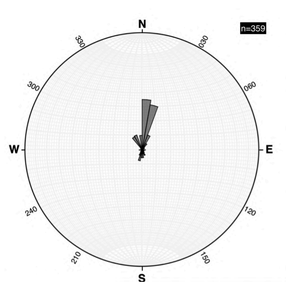
- Defined joint sets and evaluated orientations using rose diagrams and stereonets.
- Interpreted paleostress and fault kinematics using FaultKin analysis.

Results

1. Fracture Orientations & Lithologic Control



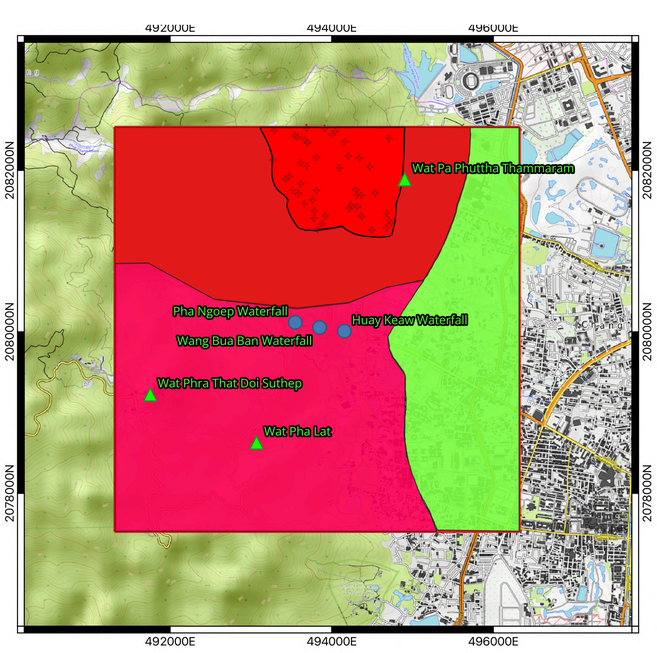
Pha Ngoep



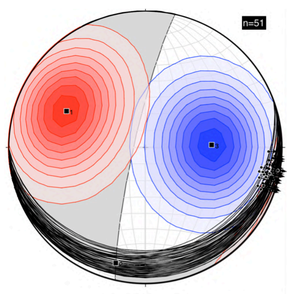
All data

- A dominant N–S joint set is observed regionally, representing the primary fracture framework.
- A secondary NNW–SSE set is localized specifically at the Pha Ngoep mylonitic zone.
- Joint apertures are strongly controlled by lithology: mylonite (Pha Ngoep) exhibits predominantly tight fractures, whereas aplite (All data) and granite show wider openings.

2. Kinematics & Stress Reorientation



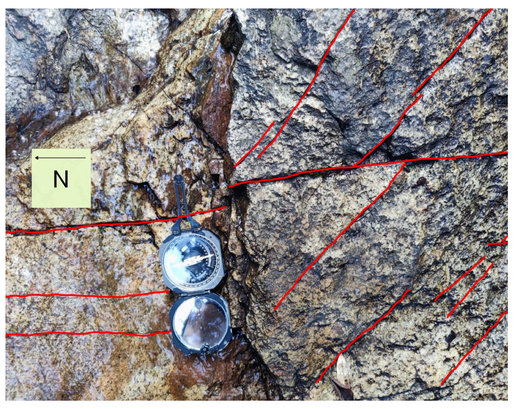
- Fault-slip data from low-angle surfaces reveal a coherent kinematic population at Pha Ngoep



- The pre-existing mylonitic fabric acts as a strong mechanical anisotropy, driving a localized stress reorientation that deviates from the regional E-W trend.

3. Relative Chronology

- Field evidence (abutting relationships) confirms a multi-stage brittle deformation: the N–S set (J1) formed earlier and was subsequently overprinted by the NNW–SSE set (J2).



Conclusion

- Fracture Sets & Lithologic Control: Two principal brittle trends were identified: a dominant N–S set and a localized NNW–SSE set. Joint apertures systematically vary with lithology, showing predominantly tight joints in mylonite and wider apertures in aplite.
- Relative Chronology: Cross-cutting and abutting field evidence establishes a multi-stage brittle deformation history. The N–S joint set (J1) formed earlier and was subsequently overprinted by the younger NNW–SSE set (J2).
- Kinematics & Tectonic Link: Fault-slip data from low-angle surfaces suggest localized kinematic coherence at Pha Ngoep. The older N–S framework links to regional extension during the Chiang Mai Basin development, while the younger NNW–SSE set reflects later stress reorganization influenced by pre-existing mylonitic fabrics.

Reference

[1]Allmendinger, R.W., Cardozo, N. and Fisher, D. (2012). Structural Geology Algorithms: Vectors and Tensors. Cambridge: Cambridge University Press.
[2]Bunma, C., 2024. Structural kinematics of Chiang Mai low-angle normal fault, western margin of Chiang Mai Basin, Northern Thailand [Unpublished independent study report]. Department of Geological Sciences, Chiang Mai University.
[3]Doblas, M. (1998). Slickenside kinematic indicators. Tectonophysics, 295, 187–197.
[4]Doungkaew, N., 2024. November 18. Quantifying fracture clustering in Chiang Mai granite: A methodological approach using normalized correlation count with implications for tectonic evolution and CO2 sequestration [Poster presentation]. International Association for Gondwana Research (IAGR) Conference, Kushing, Malaysia.
[5]Fossen, H. (2016). Structural Geology (2nd ed.). Cambridge: Cambridge University Press.
[6]ISRM (1978). Suggested methods for the quantitative description of discontinuities in rock masses. International Journal of Rock Mechanics and Mining Sciences & Geomechanics Abstracts, 15(6), 319–368.
[7]Morley, C. K., 2009. Geometry and evolution of low-angle normal faults (LANFs) within a Cenozoic high-angle rift system, Thailand: Implications for sedimentation and mechanisms of LANF development. Journal of the Geological Society. 166(1), 69–83.
[8]Norton, M. (2008). Brittle Ductile (image file: Brittle Ductile.png). Wikimedia Commons.
[9]Passchier, C.W. & Trouw, R.A.J. (2005). Microtectonics (2nd ed.). Geological Magazine 144(3), 604.
[10]Petit, J.P. 1987. Criteria for the sense of movement on fault surfaces in brittle rocks. Journal of Structural Geology, 9, 597–608.
[11]Pinet, N., Brake, V. and Lavoie, D. (2015). Geometry and regional significance of joint sets in the Ordovician–Silurian Anticosti Basin: new insights from fracture mapping. Geological Survey of Canada, Open File 7752.
[12]Rhodes, B. P., & Blum, M. D., 2000. Structural development of the Mid-Tertiary Doi Suthep Metamorphic Core Complex and Western Chiang Mai Basin, Northern Thailand.Journal of Asian Earth Sciences. 18(1), 97–109.
[13]Zhang, S., Zhu, G., Liu, C., Li, Y.J., Su, N., Xiao, S.Y. and Gu, C.C. (2018). Strike-Slip Motion Within the Yalu River Fault Zone, NE Asia: The Development of a Shear Continental Margin. Tectonics, 37(6), 1771–1796.