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# Development of deep-seated joint sets in the different stages of mountain building: a preliminary study in the northern fold-and-thrust belt of Taiwan

Jian-Cheng Lee (1), Hao-Tsu Chu (2), Jacques Angelier (3), and Françoise Begerat (4)

(1) Academia Sinica, Institue of Earth Sciences, Taipei, Taiwan (jclee@earth.sinica.edu.tw), (2) Central Geological Survey, Taipei (chuht@moeacgs.gov.tw), (3) Observatoire Océanologique de Villefranche, Géosciences Azur, France (jacques.angelier@geoazur.obs-vlfr.fr), (4) ISTeP, UMR 7193 CNRS-UPMC, Paris, France (francoise.bergerat@upmc.fr)

Systematic joint sets are one of the most common and persistent features within a brittle deformation regime, usually found in intact rocks, such as massive sandstone. However, joint occurrence can take place under different circumstances from very shallow to rather deep crust, which raise challenges for understanding the mechanisms of its development and thus provokes debates in past decades. In this study, we characterize the deformation structures, including micro fault and joint, by comparing their geometric relation with stratigraphic bedding plane. We intend not only to differentiate the relative chronology of different structures but also to determine the chronological orders and stages during thrust stacking processes in which rocks buried to certain depths and then exhumed from depths to surface. We take the northern fold-and-thrust belt of Taiwan as our case study area. The study area is composed of Pleistocene to Oligocene, terrestrial to shallow marine sedimentary deposits, which was exhumed accompanied with a series of imbricate thrusts during the Plio-Pleistocene orogeny of arc-continent collision between the Philippine Sea and Eurasian plates. We study four cross sections from little deformed rock formations in the foreland to intense folded and even slightly metamorphosed terrains in the slate belt, in order to characterize and distinguish different brittle structures at different depths. Particular attention is paid to the development of the joint sets at different depths and their relationship with the bedding plane and other associated deformation features where joints happen to occur. We found that 1) the most predominant joint sets are deep-seated and tectonics related, in comparison with shallow released joints, although their relation with tectonic stress orientation remains inconclusive; 2) the onset depths of development of joint sets can be as shallow as 3-4 km and as deep as 10-15 km. As to whether the development occurs during burial or exhumation, it remains questionable; 3) micro faults with striated slip, mainly under NW-directed compression induced by indentation of the Philippine Sea plate, occur exclusively after formation of persistent joint sets and often during thrust stacking or folding; 4) joint sets often serve as the guiding slip planes for a large portion of strike-slip micro faulting. In contrast, many thrust micro faults use bedding planes for their slip planes, especially during stacking and folding processes.