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Anatomy of gravitationally deformed slopes

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Deep-seated gravitational slope deformation is the deformation of rocks as well as slope surfaces, but the internal structures have not been well observed and described before. This is mainly due to the difficulty in obtaining undisturbed samples from underground. We analyzed the internal deformational structures of gravitationally deformed slopes by using high quality drilled cores obtained by hybrid drilling technique, which has been recently developed and can recover very fragile materials that could not be taken by the conventional drilling techniques.

Investigated slopes were gravitationally deformed out-facing slopes of pelitic schist and shale. The slope surfaces showed deformational features of small steps, depressions, knobs, and linear depressions, but had no major main scarp and landslide body with well-defined outline. This is indicative of slow, deep-seated gravitational deformation. Most of these small deformational features are hidden by vegetations, but they are detected by using airborne laser scanner.

Drilled cores showed that the internal deformation is dominated by the slip and tearing off along foliations. Slippage along foliations is conspicuous in pelitic schist: Pelitic schist is sheared, particularly along black layers, which are rich in graphite and pyrite. Graphite is known to be a solid lubricant in material sciences, which seems to be why shearing occurs along the black layers. Rock mass between two slip layers is sheared, rotated, fractured, and pulverized; undulation of bedding or schistosity could be the nucleation points of fracturing. Tearing off along foliations is also the major deformation mode, which forms jagged morphology of rock fragments within shear zones. Rock fragments with jagged surface are commonly observed in “gouge”, which is very different from tectonic gouge. This probably reflects the low confining pressures during their formation. Microscopic to mesoscopic openings along fractures are commonly observed with fractures, which also suggests the low confining pressures.

Vertical distribution of gravitational deformation with above features indicates that gravitational shear zones are nucleated in a distributed manner, then gradually connected to each other, and finally cut through the whole slope. This is the transition of gravitational mass rock creep to rock slide. First nucleation points seem to be controlled by the heterogeneity of rock properties. Thick black layers in pelitic schist, shale near thick sandstone beds in sedimentary rocks, were such nuclear points.

The geometrical relationships between the distribution of fracture zones and the slope morphology suggest that they are formed in accordance to the valley incision and resultant slope destabilization.