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Structural geology, physical properties, fault zone characteristics and stress state in scientific drill holes of Taiwan Chelungpu fault drilling project

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To understand the physics of the 1999 Chichi earthquake continuously coring and a suit of geophysical measurements were collected in the TCDP drill holes from a depth of 500 to 2003 m (hole-A) and 950 to 1352 m (hole-B), respectively. Physical properties of formations obtained from wire-line logs including P- and S-wave sonic velocity, gamma ray, electrical resistivity, density and temperature, are primarily dependent on parameters such as lithology, depth and fault zones. The average orientation of bedding, identified from both cores and FMI (or FMS) logs, is dipping about 30 degrees towards SE. Nevertheless, local azimuthal variations and increasing (from 30^o to 75^o) or decreasing (from 70^o to 20^o) bedding dips appear across fault zones. A prominent increase of structural dip to 60^o-80^o below 1856 m could be due to deformation associated with propagation of the Sanyi fault.

A total of 12 fault zones identified in hole-A are located in the Plio-Pleistocene Cholan Formation, Pliocene Chinshui Shale and Miocene Kueichulin Formation. The shallowest fault zone at depth 1111 m (FZ1111), with over 1 m long gouge zone including 12 cm thick indurate black material is the slip zone during Chichi earthquake. FZ1111 is characterized by: 1) bedding-parallel thrust fault with 30-degree dip; 2) the lowest resistivity; 3) low density, Vp and Vs, 4) high Vp/Vs ratio and Poisson's ratio; 5) low energy and velocity anisotropy, and low permeability or fluid mobility within a homogeneous gouge zone; 6) increasing gas (CO_2 and CH_4) emissions, and 7) appearance of Smectite within the primary slip zone.

In-situ stresses at the drill site were measured by leak-off tests and analyzed by borehole breakouts and drilling-induced tensile fractures from borehole FMI logs and shear seismic wave anisotropy from DSI logs. The populated fast polarization direction of shear wave is in good agreement with an overall azimuth of regional maximum horizontal stress axis, particularly within strong anisotropic Kueichulin Formation; A conjugate set of secondary directions are coaxially oriented with preferred microcrack orientations. A drastic change of orientation of fast shear wave polarization across the Sanyi thrust fault at the depth of 1712 m occurs coherently with the change of stratigraphy, physical properties and structural geometry.