Determination of three-dimensional in situ stresses from anelastic strain recovery (ASR) of Wenchuan Earthquake Fault Scientific Drilling-1 (WFSD-1)

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The stress existing in the crustal rock mass is called in-situ stress. The ASR (short for anelastic strain recovery) technique is widely used in deep 3-D stress measurements of rocks in crustal drilling, especially in seismic fracture zones with complex geologic conditions and broken formations. Well WFSD-1 is the first among the 4 scientific boreholes drilled in the project "Scientific Drilling in Seismic Fracture Zones of Wenchuan", which was implemented soon after the great May 12 earthquake. It is located at Hongkou Township, Dujiangyan City, Sichuan Province, in the hanging wall of the causative Yangxiu-Beichuan fault with relatively large horizontal dextral displacement and vertical displacement. The well depth is 1201 m and the vertical depth is 1179 m. Following the requirements of the ASR method, a total of 7 samples were collected, yielding the orientations of the maximum principal stress σ_1 as 291 ~ 325° (N35 ~ 69ºW), averaging 309°. With deepening of the borehole, they show a trend from NW to NWW. The values of the maximum, intermediate and minimum principal stresses, the vertical stress, and the maximum and minimum horizontal stresses (σ_1, σ_2, σ_3, σ_v, σ_H and σ_h respectively) at the 7 measuring points were calculated based on the average density of rocks provided by logging data, and the principal stresses and horizontal stresses roughly show linear relations with depth. The relations between σ_H, σ_v and σ_h reveal the vertical inhomogeneity of the structural state in Well WFSD-1. Generally, the relations between the horizontal and the vertical stress values show that at the depths of above 427−465 m, from 427−465 m to 800−1000 m 427−465 m, 800−1000 m and below 800−1000 m, they are $\sigma_v > \sigma_H > \sigma_h$, $\sigma_H > \sigma_h > \sigma_v$ and $\sigma_H > \sigma_v > \sigma_h$ respectively (Fig. 11, Table 2), indicating that above 427−465 m, it is in normal slipping; from 427−465 m to 800−1000 m and below 800−1000 m, they are in compressive and dextral strike-slip states respectively The ASR measurement results of WFSD-1 support the conclusion on the focal mechanism solution that the May 12 earthquake is dominated by thrusting accompanied by dextral strike-slip faulting. The orientations of σ_1 are roughly correlatable with the displacement direction of the Longmenshan area, which indicates that there are indeed movements from NW to SE, i.e. compression of the Songpan-Garzê block toward the Sichuan basin. Therefore, from a macroscopic view, the ASR technique can well be applied to the in-situ stress measurerment of cores deep in seismal fracture zones, serving as an important supplement to other methods.