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Research Advances

In-situ Stress Measurements in the WFSD-1 Borehole at the Wenchuan Earthquake Fault

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This study, supported by the Science and Technology Project of China (grant no. WFSD-00003), focuses on the in-situ stress measurements in the WFSD-1 borehole and has achieved considerable progress.

Stress is defined as the natural stress existing between rocks in the Earth's crust, and in-situ stress measurements are the main methods used to obtain records of the stress state. The Wenchuan Fault Scientific Drilling (WFSD) project used differential strain analysis (DSA) to confirm in-situ stress measurements.

The WFSD-1 borehole, the first drilling well of the WFSD project, is located in Pengguan miscellaneous rocks at the Yingxiu–Beichuan fault, which belongs to the Wenchuan earthquake fault zone. The depth of the drilling well is 1201.50 m, and the main interface of the seismic fault is located at a depth of 590 m in the drilling well, where the surrounding lithology is mainly Proterozoic granite and sandstone, but at bottom of the well (Fig. 1a) there are Triassic metamorphic sandstone and slate. To obtain the in-situ stress state of the WFSD-1 borehole and the stability of the Yingxiu–Beichuan faults, stress measurements were carried out with the DSA method, based on the revealed lithological characteristics.

Twelve samples were obtained from WFSD-1 (Fig. 1a). The strain gauges of samples were arranged in a 120° direction (Fig. 1b), and the samples and the compensation body were put together into a high-pressure container (Fig. 1c) and slowly pressurized to 100–140 MPa. Thus, the fissures gradually closed, and the parameters such as temperature, pressure, and strain were obtained for the 12 samples (Fig. 1d). The principal stress axis ratio, spindle azimuth, and inclination angle were then obtained according to differential strain curve analysis (Fig. 1e and Fig. 1f), and the three-dimensional principal stress values

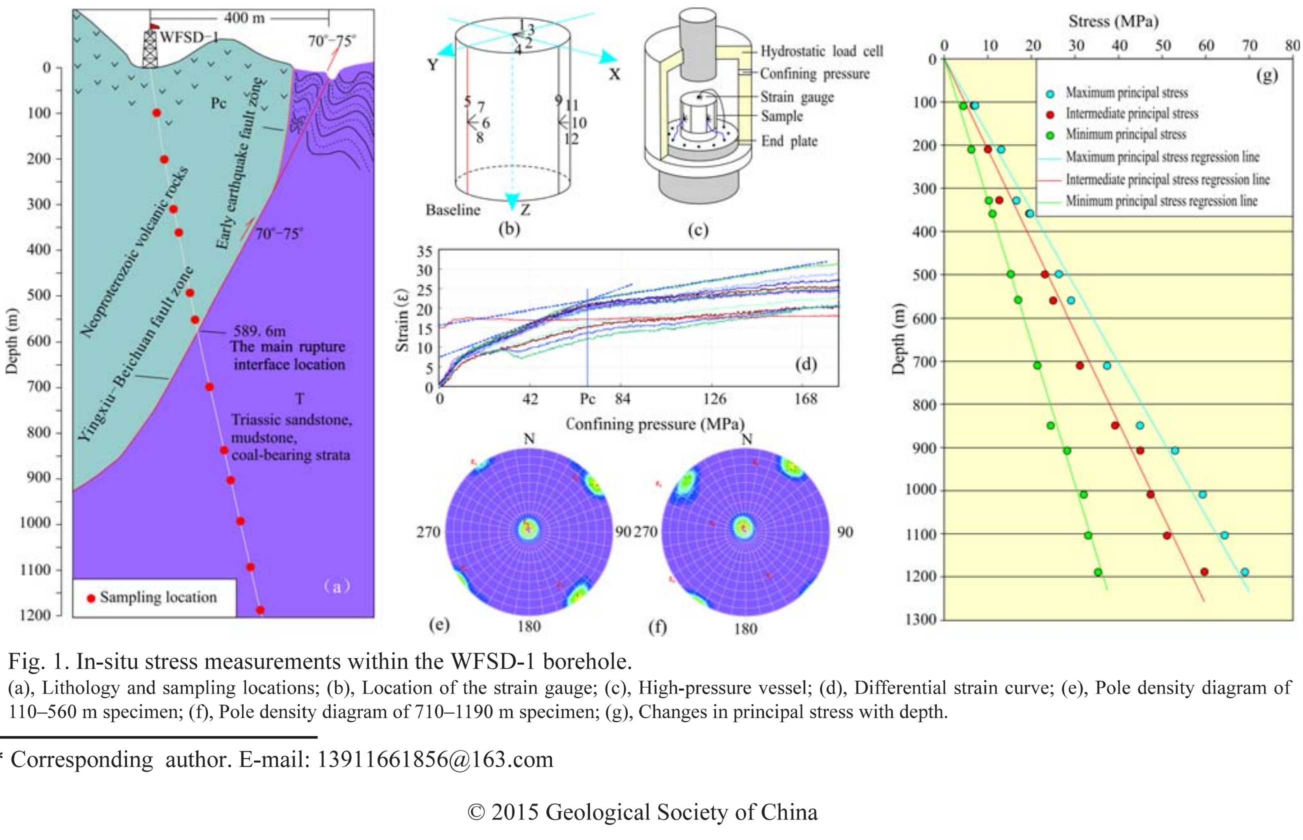

Fig. 1. In-situ stress measurements within the WFSD-1 borehole.
(a), Lithology and sampling locations; (b), Location of the strain gauge; (c), High-pressure vessel; (d), Differential strain curve; (e), Pole density diagram of 110–560 m specimen; (f), Pole density diagram of 710–1190 m specimen; (g), Changes in principal stress with depth.

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calculated by the closure pressure value of the micro cracks import to the principal stress ratio (Fig. 1g).

To analyze the stability of the fault, Coulomb criterion is accepted as the reverse faults slide criterion (Byerlee, 1990). According to stress state of each measuring point of WFSD-1, the calculated ratio (K) of σ_1/σ_3 was 1.5–2.6. Thus, most of the strata that appeared to be located at upper wall (a depth of <580 m) in WFSD-1 are stable, because most of the results at these depths were above μ = 0.5. However, at footwall (a depth of more than 600 m), the K values of the rock body were mostly above μ = 0.6, indicating very poor stability.

The achievements and conclusions of this study are illustrated as follows:

(1) Twelve samples from WFSD-1 were measured, and the average value of the maximum horizontal principal stress direction was found to be NE 330.58°. There is a significant difference in the stress state between upper wall and footwall of the fault.

(2) The stress profile in WFSD-1 was established, and it was found to increase with depth. The maximum main stress value of the borehole was found to be 7.1–69.1 MPa, and this value can be categorized as a middle-high stress state of a reverse fault.

(3) The measured ratios of the maximum and minimum principal stresses were close to 2.0. Therefore, rocks at a depth of 580 m are considered to be relatively stable, whereas rocks at depth of more than 600 m have poor stability.