

Stress orientation at the Nojima fault core estimated from fault slip detected by borehole televiewer

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The GSJ drilled a borehole penetrating the Nojima fault one year after the 1995 Kobe earthquake. We have conducted an ultrasonic borehole televiewer logging (BHTV). Within and just below the core of the Nojima fault (623.1 - 625.3 m), the borehole cross sections obtained by BHTV images show irregular shape. We interpreted this is caused by the fault slip along the preexisting fracture. We analyzed the slip directions, slip types and strikes and dip angles of the fractures in order to estimate the stress orientation at the Nojima fault core.

In normal intervals, the cross sections are circular. However, at seven depths within and just below the Nojima fault core, we can detect the displacements related to fault slips along the fractures. A circle with a diameter almost equal to that of drill bit fits only part of the cross section. A second offset circle is required to fit the other part of the cross section. The offset between the two circle centers represents the horizontal component of the slip vector. Strike and dip angle of the preexisting fractures are estimated by fitting sinusoidal curve on the borehole wall images. We can also classify the fault slips into three slip types (normal, reverse and strike-slip fault) by identifying the features of shear displacement.

It is important to understand the stress field near the fault zone because of verification of the earthquake models. However, it is difficult to measure the stress in the fault zone by core measurement or hydraulic fracturing since we hardly obtain the measurable core sample or stable borehole wall in the fault zone. Therefore it is highly necessary to develop the stress estimation method using fault slip detected by BHTV, which can be applied for the fault zone.

In the present study, we try to estimate the azimuth of maximum horizontal compressive stress (SHmax) and the parameter p at the Nojima fault core. The p expresses a linear relation between principal stresses, defined as $p = (S_2 - S_3)/(S_1 - S_3)$.

We assume that a) stress system is defined by horizontally and vertically oriented principal stress and b) the slip direction corresponds to that of the maximum shear stress acting on the fracture. According to the mechanics that the slip direction on the fracture with any strike and dip angle depends on both the direction of the horizontal stress and the relative values of three principal stress, we estimated the range of the direction of SHmax and value of p for each SHmax direction at seven depths where fault slip occurred. It is under discussion about the stress state at the Nojima fault core derived from the above analysis. One possible interpretation is as follows.

The features of the fault slips indicate that two types of slip, reverse and strike-slip fault, exist together in the depth range of 8 m around the fault core. And it is reasonable to consider that the values of principal stresses do not change a lot in the 8 m section. These imply that the value of vertical stress equals to that of minimum horizontal stress or that the difference of two stress values is small enough to be disregarded. In the above case, the parameter p equals to 0 or is approximated to be 0. Thus we need to determine the direction of the SHmax where p equals to 0. When the fault slip is strike-slip type, we can determine one possible SHmax direction at p to be 0. At five depths with strike-slip type, the directions of SHmax are distributed from N to N50E. At the other depths where the slip type is reverse, there are two possible SHmax at p to be 0, which directions are N40E and N50-70W. Assuming that directions of SHmax have same trend in the 8 m depth range, we can choose SHmax with N40E direction at the depths of reverse slip type. Therefore, the direction of SHmax at the Nojima fault core is estimated to be from N to N50E, which is almost parallel to the strike of the Nojima fault. This implies that nearly perfect stress drop has occurred in the 1995 Kobe earthquake.