

## Permeable fractures detected by geophysical loggings and their relation to in-situ stress

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We examine a relation between the orientation of permeable fractures and the state of in-situ stress by using several logging data measured in 16 boreholes at hard rock sites. Geological Survey of Japan, AIST has constructed 16 integrated borehole observation stations in and around the Kii Peninsula and the Shikoku Island since 2006. Three boreholes with different depths of about 600, 200, 30 m were drilled at each site and various kinds of geophysical loggings were conducted. We obtained the values of strike and dip angle of all fractures including the permeable ones from the borehole wall images of borehole televiewer/camera. Permeable fractures intersecting the borehole were detected by analyzing the logging data of fluid electric conductivity, sonic and temperature. The magnitude and orientation of horizontal principal stress were estimated from hydraulic fracturing stress measurements at 6 sites and the orientation of maximum horizontal stress (SHmax) were evaluated at 11 sites from the images of borehole breakout and/or induced tensile fracture.

The preliminary results from the 6 hydraulic fracturing sites are as follows: The total numbers of all fractures and the permeable ones at each site are in ranges from about 2,000 to 5,000 and from about 20 to 30, respectively. The distribution of the orientation of all fractures at each site shows various values of strike and dip angle. We classify the fractures in three types: tensile fracture (Mode I fracture), shear one and others among the distribution by considering the in-situ state of stress at each site. The tensile type has orientations parallel to SHmax and relatively high dip angles. The shear fracture is optimally oriented for shear failure in the current stress field. It is difficult at any sites to say that characteristics of the distribution of the orientation of all fractures are described only with tensile or shear failure types. Next, an examination of the permeable fracture orientation shows that large number of the permeable ones at the Niihama site have strike orientations almost parallel to SHmax and high dip angles. This feature is different from that for all types of fractures at this site. This suggests that the current stress field controls the existence of the permeable fractures at Niihama site. On the other hand, the distributions of the orientations of permeable fractures at other 5 sites have different characters from the Niihama case: The orientations of permeable fractures have the same tendency with all fractures including non-permeable fractures.

Keywords: permeable fracture, geophysical logging, in-situ state of stress, tensile fracture, shear fracture