Japan Geoscience Union Meeting 2014
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SCG65-P01 Room:Poster Time:May 2 16:15-17:30

Comparison of stress modeling with in-situ strain monitoring at seismogenic area in South African gold mines

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Compared with continuous in-situ strain monitoring in other mines, we discussed the time evolution of stress in rock mass at a depth of 3.3km for a ˜1.5-year period 90m beneath a dip pillar at Mponeng mine. The pillar contained a 30m-thick dyke which a ML2.1 seismic event obliquely bisected. We analyzed the recordings of two multi-component Ishii borehole strainmeters which had been already installed nine months prior to the ML2.1 event. One of the strainmeters was installed in the dyke (gabbros) and the other in the host rock (quartzite) near the dyke contact, both being within a few tens of meters from the ML2.1 rupture plane.

The magnitudes and directions of the principal strain changes were similar for both strainmeters in the period prior to the ML2.1 event. This suggested that the increase in stress in the dyke was significantly larger because the dyke was significantly stiffer than the host rock.

After the ML2.1 event, associated with the start of mining on the eastern side of the strainmeters, the pattern of deformation changed between the two strainmeters.

The above-mentioned characteristics of deformation were compared with numerically modelled deformation by an elastic boundary element method using Map3D Fault-Slip. The magnitude of the Map3D strain changes were, however, several times smaller than the observed strain changes both prior to and after the ML2.1 event. The rock mass just around a stope in deep tabular mining is fractured and behaves time-dependently and non-linearly. Whatever the inelastic deformation, the stress field in an elastic area can be reproduced within reason provided that the boundary condition (deformation, force or stress) is appropriately specified on the elastic-inelastic boundary. Because it is well known that time-dependent inelastic stope closure is much larger than instantaneous elastic stope closure, as a trial, we analyzed a response to an additional forced stope closure using Map3Di (Seismic Integrator version). It was then found that the forced additional stope closure better accounted for both the magnitude and the deformation pattern observed by in situ strain monitoring. We concluded that the effect of inelastic deformation around the stope was significantly larger than the elastic effect induced by the advance of mining faces, and the direct effect of the very close ML2.1 event was not so significant.

A great amount of better maintained data sets of strain are now being accumulated in four gold mines, which will allow us to discuss in further depth.

Keywords: SA gold mines, Seismogenic areas, In-situ strain continuous monitoring, Stress time evolution

SCG65-P02 Room:Poster Time:May 2 16:15-17:30

Distribution of fault plane solutions of smaller events associated with the motion of Kuril forearc sliver

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In order to find the direct evidence of motion of fore-arc sliver along the Kuril trench, we investigated the distribution of fault plane solutions along the estimated boundary of Kuril fore-arc sliver in Hokkaido. Using the P-wave polarity data as well as P- and SH-wave amplitudes, we determined the fault plane solutions of smaller events ($2.0<M<3.5$) with the number of P-wave polarity data are 10 or greater. The result is summarized as follows. Along the volcanic front in eastern Hokkaido, strike-slip fault type of events with WNW-ESE trending P-axes are distributed, which is consistent with the motion of Kuril fore-arc sliver along the volcanic front. In the western side of Hidaka Mountains, reverse fault type of events with P-axes sub-parallel to the trench are widely distributed, which is consistent with ongoing process of collision of Kuril fore-arc sliver with northeastern Japan arc. In more detail, we found that reverse fault type of events with NE-SW trending P-axes, which rotates counterclockwise from trench parallel direction are concentrated near the epicenter of 1982 Urakawa-oki earthquake (M7.1). The P-wave velocity perturbation derived from tomography study for the lower portion of the overriding plate show a good correlation with the distribution of events with NE-SW trending P-axes. The seismic tomography study suggests that the lower half of the delaminated lower crust extends to the source region of the 1982 Urakawa-oki earthquake, which may cause counterclockwise rotation of P-axes near the epicenter of 1982 Urakawa-oki earthquake (M7.1).

SCG65-P03 Room:Poster Time:May 2 16:15-17:30

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

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SCG65-P04 Room:Poster Time:May 2 16:15-17:30

Change in paleostress in offscraped accretionary complex, Kayo formation, the Shimanto Belt, Okinawa island

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It is important to understand a stress state of subduction zone because it is strongly related to development of accretionary complex, strength of fault, geometry of subduction zone and earthquake process. The purpose of this study is to examine paleo-stress in a off-scraped accretionary complex in Shimanto Belt, Okinawa island.

The study area is Kayo formation in the northeastern coast of Okinawa island. The Kayo formation consists mainly of coherent turbidites, and it was highly deformed by folds and thrusts. Those geological structures of the formation represent characteristics of fold-thrust belt in forearc area[Ujiie,1998].

Flexural slip associated with folding is commonly observed. In addition, many micro-faults cutting bedding are also observed. On the slip surfaces both of flexural slip surfaces and micro-faults, slicken lines and slicken steps are identified. From the structures, slip data (strike and dip of fault plane, slip direction and slip sense) was obtained.

The number of slip data for micro-fault is 153 in ˜2 km wide of study area. Using the slip data, we conducted micro-fault inversion analysis to examine the stress orientation and stress ratio. The stress ratio is defined as ϕ=(σ2-σ3)/(σ1-σ3). We used software MIM (Yamaji,2000) for stress analysis and K-means clustering (Ostubo et al, 2007) for automated picking of center of cluster. After the stress analysis, we combined the stress data with stress polygon to examine stress magnitude semi-quantitatively. The stress polygon is based on Anderson ' s theory. We assumed the vertical stress is always gravity force, which is converted from assumed depth.

As a result of analysis, 4 stress solution (KY1-KY4) were obtained. KY1) NE-SW horizontal compression with high stress ratio, (ϕ=0.88), KY2) KY3) NW-SE high angle compression with low to intermediate stress ratio (ϕ=0.22,0.45), and KY4) NW-SE horizontal compression with intermediate stress ratio (ϕ=0.65).

We picked up the micro-fault with misfit angle less than 40? for each stress. Misfit angle is the angle between calculated slip direction and observed slip direction on the micro-fault surface. Reverse faults are dominant in KY1 and KY4 and normal faults are dominant in KY2 and KY3.

The stresses are projected to horizontal surface and to Shmax (perpendicular to fold axis), Shmin (parallel to fold axis), and Sv. Using stress ratio and stress projection above, linear functions in Shmax and Shmin space are obtained. We can examine the semi-quantitative Shmax and Shmin value for the stresses in overwrapping area between the linear functions and stress polygon.

Magnitudes of shear stresses for KY2, KY3, KY1 and KY4 on the horizontal decollement were also estimated as τ2=39.2˜54.7[MPa], τ3=52.1˜64.2[MPa] and τ1=79.0˜212.3[MPa], τ4=48.0˜137.7[MPa]. The shear stress for reverse fault (KY1, KY4) is bigger than the shear stress for normal fault (KY2, KY3). If the differences in stress represent the stress change in seismic cycle, the differences in shear stress indicate stress drop as -16.2˜173.1[MPa]. Stress drop in general earthquake ranges 0.03˜30[MPa]. The obtained stress drop in this study includes the range of general stress drop.

Keywords: Stress, micro-fault inversion, Shimanto Belt, Okinawa