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Ground Motion Polarization in Fault Zones: Its Relation with Brittle Deformation Fields

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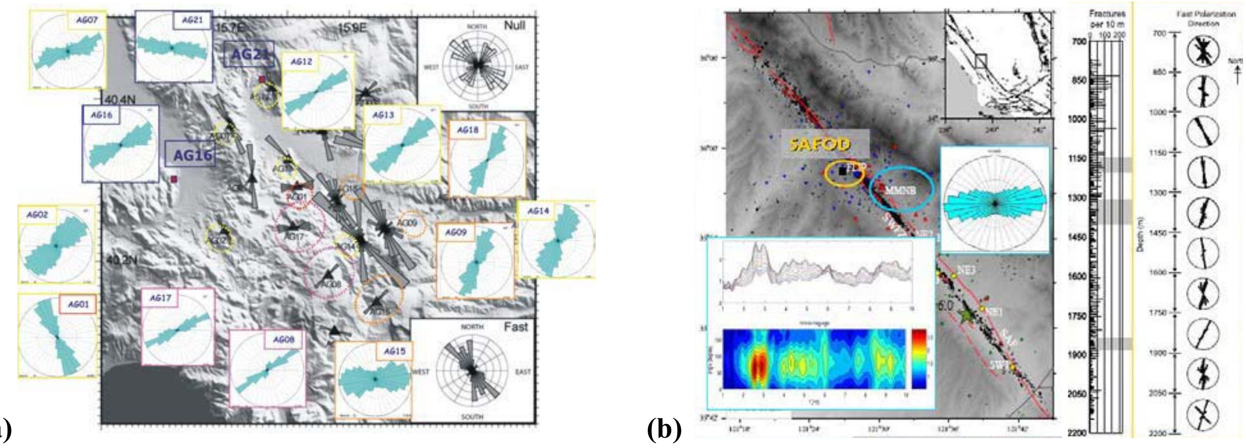
Recent studies have found that ambient noise and seismic signals in fault zones tend to be polarized on the horizontal plane with a predominant orientation [Rigano et al. 2008; Di Giulio et al. 2009; Cara et al. 2010; Falsaperla et al. 2010; Pischiutta, 2009; Pischiutta et al. 2010]. Here we present a summary of past experiments as well as new case studies showing evidence of this effect. The approach combines the H/V technique in the frequency domain with the covariance matrix diagonalization method [Jurkevics, 1988] in the time domain. Common features are: *i)* a high stability of results at each site, independently of the nature and location of the source of seismic signals, *ii)* a predominant polarization that is characteristic for each fault, and *iii)* polarization is not parallel to the fault strike as it would be expected for fault-trapped wave generation.

In previous papers, a role of fluid-filled micro-cracks in the damage zone was hypothesized [e.g., Di Giulio et al. 2009]. If this is true, a correlation is expected between seismic anisotropy and polarization. In the studied faults, when anisotropy results are available, the horizontal ground motion polarization is found to be perpendicular to the fast wave splitting component, confirming the role of fluid-filled micro-cracks in the damage zone. In Figure 1 the orientation of horizontal polarization and the direction of the S wave fast component are shown for two case studies: the Val d'Agri basin (southern Italy) and the San Andreas fault.



(a) (b)

Figure 1. Perpendicularity relation between seismic anisotropy and the orientation of horizontal ground motion polarization on seismic events recorded in two studied areas. (a) Val d'Agri extensional basin (southern Italy): the horizontal polarization at each station site (cyan rose diagrams) is calculated from up to 30 seismic events and compared to the S wave fast component direction (grey rose diagrams) obtained from the S-wave splitting [Pastori et al. 2009]. (b) San Andreas fault, Parkfield sector. Comparison between the horizontal polarization of 2,000 earthquakes recorded in 2004 at the borehole station MM (cyan rose diagram) and the S wave fast component direction calculated by Boness and Zoback [2004] in the SAFOD pilot hole.

We have checked this interpretation in terms of the fracture field orientation in the damage zone by applying the package FRAP3 [Salvini, 2002] to model the brittle deformation field expected in the damage zone of the studied faults. We have found that the observed polarization azimuths are consistently orthogonal to the orientation of the predicted fracture systems.

As an example we report in Figure 2 the Pernicana fault case study (Mt. Etna), where Di Giulio et al. [2009] found a strong directional effect around 1 Hz. The polaritazion azimuth varies from N160 at stations installed on the fault hanging wall (# 7, 9, 10, 11, 12 and 13) to N120 at stations on the footwall (#3, 4, 5 and 6). In order to explain the observed variation, the brittle deformation in the fault damage zone was analytically computed through the package FRAP3. We explained the observed variation of the polarization azimuth in terms of a differential probability to develop different brittle deformation fields. The synthetic cleavage (N75) is more diffuse on the fault hanging wall while extensional fractures (N40) dominate the fault footwall. A perpendicularity relation between polarization and the most diffuse fracture field is again recognized.

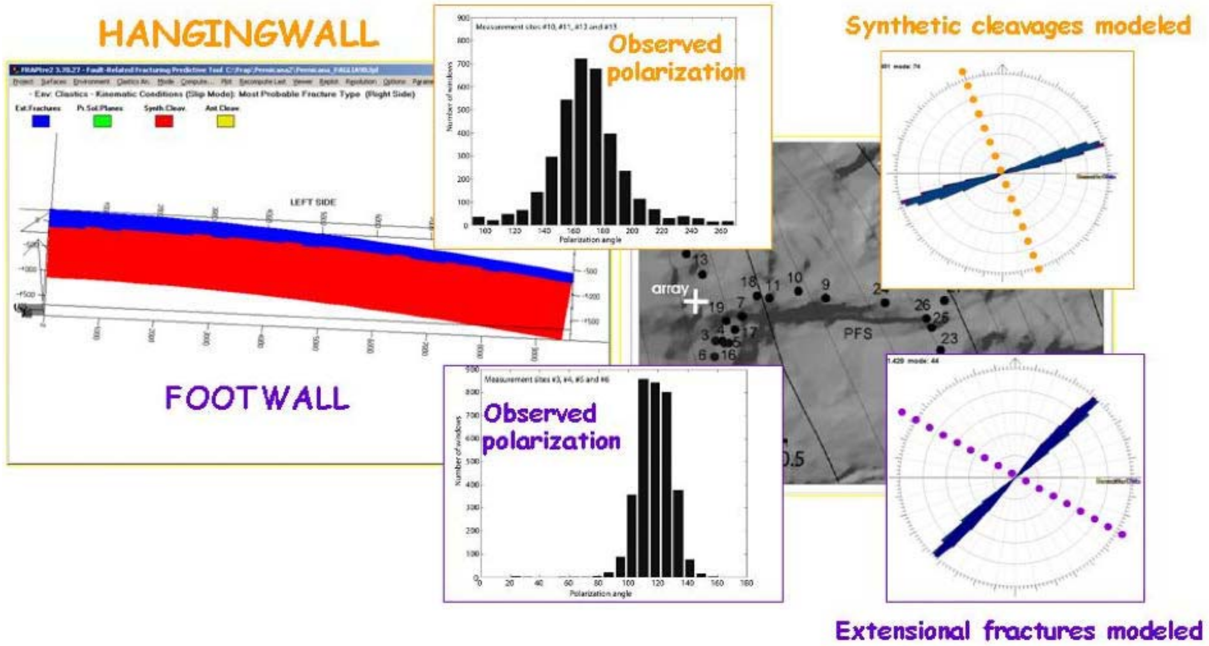


Figure 2. Most probable fracture field on the fault surface and rotation of polarization from the hanging wall to the footwall. Perpendicularity relation between polaritazion and the orientation of the most probable fracture fields (rose diagrams) both in the hanging wall (synthetic cleavages) and in the footwall (extensional fractures).

The quick and relatively inexpensive polarization method encourages to further tests for an extensive application to many fields of theoretical and applied geophysics, where indications about the orientation of fracture fields are required. In fact, polarization method yields the same information as S waves anisotropy allowing lower costs and faster measurements.

This method could be tested in geothermal areas where hydrofracturing is caused by water high-pressure injection. It could be also interestingly applied to CO_2 injection sites along with studies of focal source mechanisms, in order to detect seismicity variations due to fluid injection.

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