Scalar moment variations and isotropic characteristics of the main- and after-shock earthquakes in transform fault systems

Poster 8

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ABSTRACT

Full moment tensor inversions of main- and after- shock earthquakes with non-double couple component in the Gulf of California Transform Fault System are presented in this work. In general, the isotropic constant volume parameter k of the of the Transform Fault System is positive indicating that tensile opening cracks are the initial processes of the seismic sequences. However, for many off transform system eartquakes, the k parameter is negative, implying that closing cracks occur. In addition, the dilatational component T-ISO varies for both main- and after- shock sequences. On the other hand, the scalar moment is highly sensitive to the amount of non-double couple component and it is very different when is compared with the pure deviatoric inversions. An interesting observation is that the corner frequency remains constant for different magnitude ranges for the off transform system earthquakes.

INTRODUCTION

Rifting in the Gulf of California began ~12–15 Myr, when the East Pacific Rise (EPR) approached the paleotrench and the subduction of the Farallon plate ended, breaking into a number of microplates. Therefore rifting in the Gulf of California is a result of ridge subduction after the subducted slab was stopped [Atwater, 1970; Menard, 1978; Stock and Lee, 1994; Michaud et al., 2006]. The stress release in the vicinity of the Gulf of California transform system is poorly understood [Munguía et al., 2006]. Some intriguing questions that are yet to be resolved are related to whether the seismic activity nearby transform faults is controlled by a global tectonic motion of the plates, by regional stress release, or by local structures [Gudmundsson and Fjader, 1995; Gudmundsson, 1995a, 1995b; Bufe, 2005], and it has been commonly assumed that adjacent structures, such as the fault limbs of the transform fault, behave aseismically [Gudmundsson, 1995b].

The Gulf of California (Fig. 1) is classified as an oblique-divergent plate boundary. Less work has been done on the structural patterns of oblique rift transform systems compared to the structural patterns of orthogonal rifts [Umhoefer et al., 2002]. The dominant mode of faulting in the Gulf of California is right-lateral strike-slip motion. It was widely accepted that the Gulf of California had an early stage of orthogonal rifting previous to the modern oblique-divergent plate boundary [Oskin and Stock, 2003; Stock and Hodges, 1989]; however, this model is currently under debate, and recent authors propose that transtensional shearing was the cause of an original oblique shearing without the intermediate stage of orthogonal rifting [Fletcher et al., 2007].

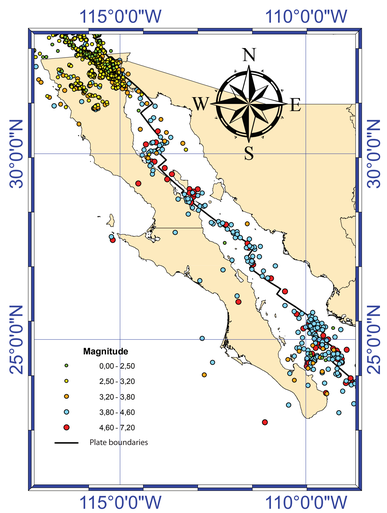


Figure 1. Seismicity map of the Gulf of California during the last 5 years from the NEIC catalog. The intense activity at the Northern part is related to the El Mayor-Cucapah earthquake of 4 April, 2010 (Mw = 7.2). At the southern part most of the activity occurred during 2007 and 2012.

SCALAR MOMENT M_O

Bowers and Hudson (1999) discussed the estimation of scalar moment M_O given a general second order moment tensor **M**. In general a tectonic earthquake is assumed to be a double couple. However, there has been a long term discussion if earthquakes at ridge transform-fault plate boundaries exhibit unusually high non-double couple parameter (Kawakatsu, 1991; Ortega and Quintanar, 2010) therefore a simple shear-dislocation fault model defined as $M_O=\mu u A$ may not be complete.

Following Bower and Hudson, a total scalar moment can be defined as:

$$M_o^T = M_I + M_D \quad (1)$$

Where $M_I = |\mathbf{M}|$ and $M_D = \max(|m'_j|)$, m'_j are the eigen values of the deviatoric moment tensor. This definition of M_o requires a full moment tensor inversion.

In general, full moment tensor inversions are not performed on a routine basis, however, as pointed by Bowers and Hudson, if the source mechanism is delimited by $k < 0$, $T > 0$ and $k > 0$, $T < 0$, where T and k are defined in Hudson et al. 1989, as the constant volume component and the volume change component respectively, then for practical purposes $M_O{}^T = M_D$. This T-k condition, namely key source type, is common in Geysers and in some tectonic environments. In the following section we will show that the key source type is not always present in transform fault system (TFS) and we will compare the scalar moment M_o from (1) with the scalar moment of the deviatoric inversion.

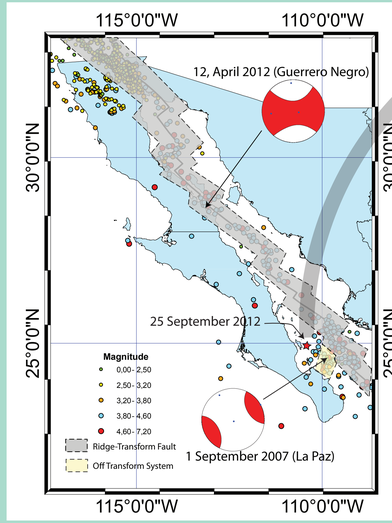
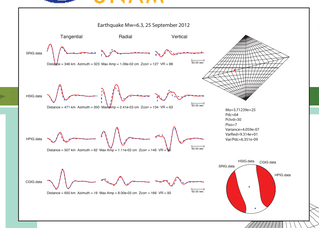


Figure 3. Tectonic regions a) Ridge-transform fault system (gray) b) off the transform system of the Gulf of California (yellow). Earthquakes that are directly related to ridge-transform system are commonly reported whereas earthquakes that lie off the ridge-transform region are rarely studied since they have smaller magnitude than those located at the fault system. In general moment tensor solutions are reported using deviatoric inversions, however, at the Extensional Province of the Gulf of California the isotropic component plays an important role in estimating source parameters. Two sample earthquakes illustrate differences in isotropic polarities that may be caused by the location of the earthquake in relation to the ridge-transform fault system. In anyway, in both cases if we plot the sources in a source type plot (see figure 5), they are outside the key source type region, suggesting that M_O differs between M_D and $M_O{}^T$. Correct estimation of M_O is important to compute corner frequencies and seismic efficiency. Moreover, an adequate estimation of moment magnitude is necessary because a pure dislocation model is not complete in this tectonic setting.



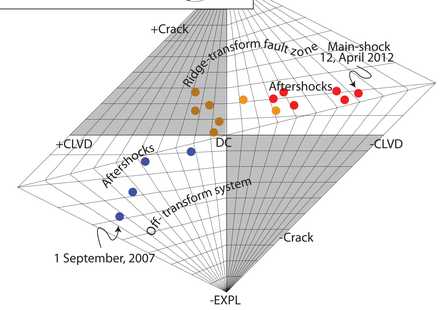


Figure 5. Source type plot of different earthquakes in the Extensional Province of the Gulf of California. At the ridge-transform fault zone the k value is positive whereas off the transform system we observed k reversals.

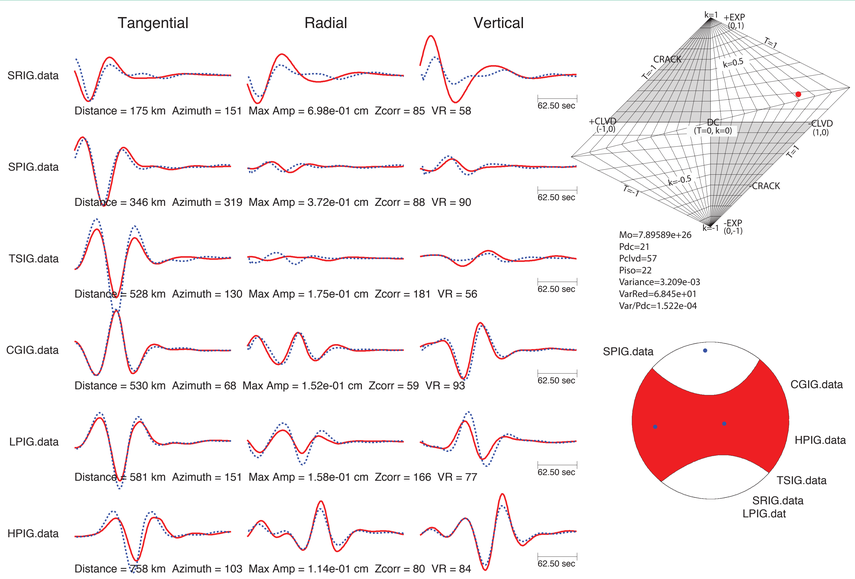


Figure 2. Full moment tensor inversion of the 12 April, 2012 Guerrero Negro earthquake (Mw=6.9). The scalar moment Mo was computed using equation (1), the T-k plot (Top, right) suggests that the earthquake lies outside the key source type region (shaded region). Therefore the scalar moment Mo of the full moment tensor is not equivalent to that of the deviatoric moment. The positive k (ordinate) suggests that there is an expansion as well as a strike-slip component at coseismic moment release, this type of source is in agreement with a Ridge-Transform Faults System tectonics. Observed (blue) and predicted (red) waveforms were filtered in the range of 120 to 50 seconds.

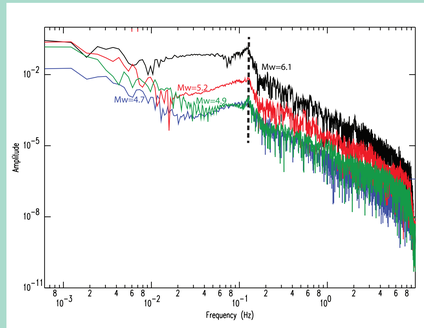


Figure 4. Displacement spectra of four selected earthquakes that occurred during the 1 September, 2007 off-transform system sequence. In the range between 4.7 to 6.1 Mw the events have virtually the same corner frequency

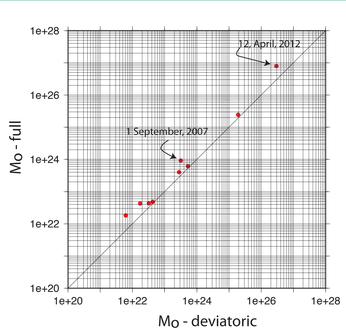


Figure 6. Comparison of Mo–deviatoric with Mo–full.

DISCUSSION

We inverted full moment tensors (Fig. 2) from different earthquakes located in the Extensional Province of the Gulf of California transform system, then we divided the tectonic regions in a) Ridge-Transform system and b) off the Transform System of the Gulf of California (Fig.3). The displacement spectra (Fig. 4) of the 1 September 2007 earthquake sequence suggest that at different scales the corner frequency remains constant, this characteristic has been observed using different techniques (e.g. coda ratio or direct S waves). In anyway, there is a wide range of source mechanisms (Fig. 5) if we plot the moment tensor solutions in the T-k domain (Hudson et al. (1989). We observe that at the Ridge-Transform system the k is positive, whereas at the off- transform system example of 1 September 2007 the k value is negative. In a Ridge-Transform System we observe that the isotropic component plays an important role in estimating the scalar moment M_o value (Fig. 6). Future work is necessary to estimate seismic efficiency or ground motion predictions in transform systems, since M_o and corner frequencies are fundamental parameters to scale earthquakes.

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