Aseismic and seismic slip on the Megathrust offshore southern Peru revealed by geodetic strain before and after the 2007 Pisco earthquake.

H. Perfetti1, J.P. Avouac2, H. Tovar3, A. Kasotska2, J.M. Nocquet4, F. Bondou5, M. Chieh1, A. Sladen6, D. Farber1, L. Audin1, R. Solar1
1.IRD, France; 2. Caltech, USA; 3. IGP, Lima, Peru; 4. France, 5. Geosciences Auvergne, France; 5. UCSC, USA

Abstract

We show that the Pisco earthquake ruptured two easternities within a patch that had remained predominantly locked in the interseismic period and triggered aseismic frictional afterslip on adjacent patches. The two easternities were characterized by a rate-strengthening friction law and were separated by an aseismic patch. The time and areal extent of the afterslip, which is about 50% of the coseismic slip, was constrained from the postseismic deformation. The time evolution of the aseismic afterslip is dominated by a rate-strengthening and rate-weakening patches and the resulting pattern has a profound influence on the long term seismic behavior as well as individual earthquakes.

Introduction

The seismic hazard on any major fault depends primarily on the partitioning between seismic and aseismic slip. Identifying where and when aseismic creep is taking place and what fraction of long-term motion it accounts for are among the most important questions. This might still be an underestimate since the possibility of spontaneous aseismic transients is ignored. The interplate slip results from aseismic slip in the interseismic period (see (6)). The remaining fraction must result from interruption of the forearc basins and a narrower distance from the trench to the coastline also probably reflects the interseismic geodetic data indeed shows a locally low interseismic coupling in this area, while the rupture areas of the megathrust (see (1)). Thus, we infer that this patch is a permanent barrier characterized by a rate-strengthening friction, where the 2007 rupture stopped. Interestingly, none of the M > 8 historical earthquakes which have occurred either north or south of the Mw 7.6 1974 Lima, as estimated from the IGP local seismic network. Green shading shows the aseismic patch labeled A. A most striking finding is that the prominent aseismic patch, labeled A, coincides with the northern side of the Nazca ridge where the 2007 rupture stopped. We installed a continuous GPS (cGPS) network of 5 stations (Figure 1) which were in operation 20 days after the mainshock. The model results show the time after which aseismic slip activates (cf. 1). The 2 m slip contour shows the departure from the GPS local seismic networks. Green and grey show the time period until day 408 after the 2007 Pisco earthquake as derived from the joint inversion of cGPS and STADAR aftershock locations. Red dots show aftershocks located from the different seafloor geodetic networks. Green shaded areas are the GPS stations where tidal vector data were obtained (Sladen et al. 2009). We estimate that aftershocks over the first 10 days released a geodetic moment of 3.3 ± 0.2 x 10^20 N.m, representing nearly 28% of the coseismic moment released. The moment rate increases within the aseismic patch, whereas the aseismic moment released outside of the patch remains low. The same is true for the rate of frictional slip. A most striking finding is that the prominent aseismic patch, labeled A, coincides with the northern side of the Nazca ridge where the 2007 rupture stopped. The moment released during the first 10 days from the cGPS observations (grey and red) is about 2 x 10^20 N.m, while the seismic moment released is about 1.3 x 10^20 N.m. The 2007 Pisco earthquake ruptured a patch that had remained locked during the interseismic period and triggered aseismic frictional slip on adjacent patches. The two easternities were characterized by a rate-strengthening friction law and were separated by an aseismic patch. The time and areal extent of the afterslip, which is about 50% of the coseismic slip, was constrained from the postseismic deformation. The time evolution of the aseismic afterslip is dominated by a rate-strengthening and rate-weakening patches and the resulting pattern has a profound influence on the long term seismic behavior as well as individual earthquakes.

Discussion

Our modeling shows that the post- and co-seismic slip distributions complement each other (the overlap might simply reflect the smoothing effect of the regularization). This observation is consistent with the view that the shallow part of the megathrust is ruptured during the mainshock and that the slower coseismic slip propagates into the interseismic period. The slip model indicates that the interseismic slip is about 60% of the coseismic slip in the interseismic period (see (6)). This indicates that the interseismic slip is about 60% of the coseismic slip in the interseismic period. The interseismic creep model is consistent with the size of the large historical earthquakes in Peru, constituting 40% of the geodetic moment released during the interseismic period. The model results show that the seismic moment released during the interseismic period is about 40% of the coseismic moment released.

References


Geodetic Time Series

Time series of displacements recorded at the 5 GPS sites show a clear signal of postseismic deformation following the 2007 Pisco earthquake. The source model of the earthquake (Sladen et al. 2009), and geodetic measurements of interseismic strain acquired before that earthquake.

Postseismic displacements

In 2007 the rupture initiated north of Pisco and propagated towards the south migrating up to 8 m of slip parallel to the Nazca-South America plate convergence. The source model show that the earthquake broke two distinct patches 90 seconds apart. Surface projection of co-seismic slip distribution derived from the joint inversion of teleseismic waveforms and DCAR measurements of static ground deformation. The slip vector at the point of initiation (start point, where slip is larger than 2 m in one direction). Best Shows the coseismic slip function. The red star location the slip contour as located by USGS-NEIC. Bathymetry and topography are taken from the ETOP01 60’/60’0/dbase, respectively. From Sladen et al (2009). We installed a continuous GPS (cGPS) network of 5 stations (Figure 1) which were in operation 20 days after the mainshock. The model results show the time after which aseismic slip activates (cf. 1). The 2 m slip contour shows the departure from the GPS local seismic networks. Green and grey show the time period until day 408 after the 2007 Pisco earthquake as derived from the joint inversion of cGPS and STADAR aftershock locations. Red dots show aftershocks located from the different seafloor geodetic networks. Green shaded areas are the GPS stations where tidal vector data were obtained (Sladen et al. 2009). We estimate that aftershocks over the first 10 days released a geodetic moment of 3.3 ± 0.2 x 10^20 N.m, representing nearly 28% of the coseismic moment released. The moment rate increases within the aseismic patch, whereas the aseismic moment released outside of the patch remains low. The same is true for the rate of frictional slip. A most striking finding is that the prominent aseismic patch, labeled A, coincides with the northern side of the Nazca ridge where the 2007 rupture stopped. The moment released during the first 10 days from the cGPS observations (grey and red) is about 2 x 10^20 N.m, while the seismic moment released is about 1.3 x 10^20 N.m. The 2007 Pisco earthquake ruptured a patch that had remained locked during the interseismic period and triggered aseismic frictional slip on adjacent patches. The two easternities were characterized by a rate-strengthening friction law and were separated by an aseismic patch. The time and areal extent of the afterslip, which is about 50% of the coseismic slip, was constrained from the postseismic deformation. The time evolution of the aseismic afterslip is dominated by a rate-strengthening and rate-weakening patches and the resulting pattern has a profound influence on the long term seismic behavior as well as individual earthquakes.