Geophysical Research Abstracts
Vol. 13, EGU2011-8335, 2011
EGU General Assembly 2011

The Fluid Flow Evolution During the Seismic Cycle Within Overpressured Fault Zones

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Understanding how fracturing processes acting during the seismic cycle can lead to the development of overpressured patches along fault zones is critical, as they can act as nucleation sites and trigger earthquakes. Rupture nucleation models have suggested that frictional instability on a pre-existing fault, leading to earthquake nucleation, may occur at small patches of locally high shear to effective normal stress ratio, when these patches are larger than a critical size LN. In order to understand what factors control the development and size of CO2 fluid overpressure patches able to trigger earthquake nucleation (i.e. $\geq$ LN) , we modeled fluid flow through a mature fault zone within the Triassic Evaporites of Northern Italy (nucleation site of the 1997 M=6 Colfiorito earthquakes). Fluid pressure and static fault zone strength evolution is dynamically modeled through the seismic cycle by assuming a simplified fault zone architecture, inferred from large fault zone analogues studied in the field, and laboratory derived fault zone mechanical and transport properties.

The fault zone architecture is given by a damage zone (DZ), made of intensely fractured dolostones and foliated anhydrites displaying little fracturing, which is juxtaposed to a fault core made of fault gouges and cataclasites. The fault core can be dived in an outer fault core (OFC), made of foliated anhydrite and cataclastic dolostone, and an inner fault core (IFC), made of foliated gouge and cataclasites. Discrete, fault-parallel PSZ accommodated most of the displacement within the IFC. Horizontal (kh) and vertical (kv) OFC permeability k, used in the model, vary according to pore fluid pressure Pf and damage produced during tectonic loading. Pore pressure and stress dependence permeability envelops have been obtained from the interpolation of static and dynamic laboratory permeability measurements. The permeability of the IFC is assumed to be low due to the presence of fine grained fault gouges. In our model we assume that horizontal khIFC (i.e. orthogonal to PSZ) and vertical (i.e. parallel to PSZ) kvIFC stay constant during the seismic cycle, i.e. they are not dependent on dynamic pore fluid pressure and stress field conditions. The k of the Dz is controlled by well-developed mesoscale fracture patterns which prevent the generation of any overpressure. Variations of pore fluid pressure Pf, above hydrostatic, in the fault zone during the seismic cycle have been obtained by solving using Matlab a non-linear diffusion equation adopting the Euler backward finite difference technique.

Our model results show that, during the seismic cycle, the lateral fluid flux, across the fault zone, is always lower than the vertical parallel fluid flux. Under these conditions fluid overpressure patches, within the fault zone, can develop and lead to the nucleation of an earthquake when their size is equal and/or larger than the nucleation length, LN. Our modelling shows that during extensional loading, overpressured fault zones within the Triassic Evaporites may develop and act as nucleation sites.