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

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The integration of seismic reflection profiles with well-located earthquakes shows that the mainshocks of the 1997 Umbria-Marche seismic sequence (Mw $>$ 5) nucleated at about 6 km depth, within the Triassic Evaporites, a 2 km thick sequence made of interbedded anhydrites and dolostones. Two boreholes, drilled northwest of the epicentral area, encountered CO2 fluid overpressures at about 0.8 of the lithostatic load, at about 4 km depth. It has been proposed that the time-space evolution of the 1997 aftershock sequence, was driven by the coseismic release of trapped high-pressure fluids (lv = 0.8), within the Triassic Evaporites. In order to understand whether CO2 fluid overpressure can be maintained up to the coseismic period, and trigger earthquake nucleation, we modelled fluid flow through a mature fault zone within the Triassic Evaporites. We assume that fluid flow within the fault zone occurs in accord with the Darcy's Law. Under this condition, a near lithostatic pore pressure gradient can develop, within the fault zone, when the upward transport of fluid along the fault zone exceeds the fluid loss in a horizontal direction. Our model's parameters are: a) Fault zone structure: model inputs have been obtained from large fault zone analogues derived from field observation. The architecture of large fault zones within the TE is given by a distinct fault core, up to few meters thick, of very fine-grained fault rocks (cataclasites and fault gouge), where most of the shear strain has been accommodated, surrounded by a geometrically complex and heterogeneous damage zone (up

to few tens of meters wide). The damage zone is characterized by adjacent zones of heavily fractured rocks (dolostones) and foliated rocks displaying little fracturing (anhydrites). b) Fault zone permeability: field data suggests that the permeability of the fault core is relatively low due to the presence of fine grained fault rocks ($k < 10E-18$ m2). The permeability of the dolostones, within the damage zone, is likely to be high and controlled by mesoscale fracture patterns ($k > 10E-17$ m2). For the anhydrites, the permeability and porosity development was continuously measured prior and throughout triaxial loading tests, performed on borehole samples. The permeability of the anhydrites within the damage zone, due to the absence of mesoscale fracture patterns within Ca-sulphates layers, has been assumed to be as low as the values measured during our lab experiments (k = 10E-17 - 10E-20 m2). 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 within the fault zone can be sustained up to the coseismic period when earthquake nucleation occurs. Our modelling shows that during extensional loading, overpressured fault zones within the Triassic Evaporites may develop and act as asperities, i.e. they are mechanically weaker than faults within the overlain carbonates at hydrostatic (lv = 0.4) pore fluid pressure conditions.