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Finding the buried record of past earthquakes with GPR-based paleoseismology

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In places where sedimentation and erosion compete at fast rates, part of the record of past earthquakes on faults may be buried, hence hidden, in the first few meters below the surface. We developed a novel form of paleoseismology, of geophysical type, based on the use of a dense pseudo-3D Ground Penetrating Radar (GPR) survey to investigate such possible buried earthquake traces, on a long, fast-slipping strike-slip fault (Hope fault, New Zealand), at a site (Terako) where marked alluvial conditions prevail. We first used LiDAR data to analyze the ground surface morphology of the 2 km^2 site at the greatest resolution. Nineteen morphological markers were observed, mainly alluvial terrace risers and small stream channels that are all dextrally offset by the fault by amounts ranging between 3 and 200 m. The measurements document about 10 past earthquake slip events with a mean co-seismic slip of 3.3 $\pm$ 1 m, with the most recent earthquake event having a slip of 3 $\pm$ 0.5 m. We then investigated a detailed area of the site (400 x 600 m^2) with pseudo-3D GPR. We measured 56, $\approx$ 400 m-long, 5-10 m spaced GPR profiles (250 MHz), parallel to the fault and evenly distributed on either side. The analysis revealed the existence of a paleo-surface buried at about 3 m depth, corresponding to the top of alluvial terraces of different ages. That buried surface is incised by a dense network of stream channels that are all dextrally offset by the fault. We measured 48 lateral offsets in the buried channel network, more than twice than at the surface. These offsets range between 6 and 108 m, as observed at the surface, yet provide a more continuous record of the fault slip. The similarity of the successive slip increments suggests a slip per event averaging 4.4 $\pm$ 1 m, fairly similar to that estimated from surface data. From the total 'surface and buried' 67 offset collection, we infer that a minimum of 30 large earthquakes have broken the Hope fault at the Terako site in the last about 6-7 kyrs, with an average co-seismic slip of 3.2 $\pm$ 1 m, a minimum average recurrence time of about 200 yrs, and a magnitude of at least Mw 7.0-7.4. Our study therefore confirms that part of the record of past earthquakes may indeed reside in the first few meters below the surface, where it may be explored with geophysical, GPR-based paleoseismology. Note that, to further test and use this novel approach, we have investigated a dozen of other sites along the major active strike-slip faults in New Zealand. We will present the preliminary GPR results that we have obtained at the Te Marua site on the Wellington fault, and will discuss them in the framework of the numerous trenches and dating data available at this site.