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Ground-truthing in-situ seismic data against geological data: the Carboneras Fault Zone, S.E. Spain

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The Carboneras fault zone (CFZ) is a major NE-SW trending tectonic lineament in SE Spain. Of Miocene through Recent age, it separates the volcanic Cabo de Gata terrain from the tract of uplifted metamorphic basement blocks and post-orogenic basins that comprise the Betic Cordilleras lying to the NW. The CFZ consists of two main strands, about 100m apart, each containing several metres thickness of low metamorphic grade, clay-bearing fault gouge, formed in the uppermost 3 to 5 km of the crust. Outside the fault cores, there is widespread cataclastic damage done to the country rocks, plus some subsidiary fault strands.

The excellent exposure of the fault rocks and their protoliths makes them particularly well suited to verifying the results of in-situ seismic investigations. Seismic methods are widely used to investigate fault rock structures, but commonly in regions that are less well exposed that the CFZ. Two high resolution seismic reflection/refraction transects were carried out in river valleys cutting the fault zone, and tomographic sections have been constructed. Samples of fault rocks and their protoliths were also collected for laboratory measurements of acoustic wave velocities. Inevitably, the shallow seismic investigations are strongly affected by the cracking on a range of scales that has been done to the country rocks during fault motions, whereas the small samples used for laboratory acoustic measurements are relatively pristine. Despite this, of course, there is still marked sensitivity of velocity to pressure at low pressures as small cracks are progressively closed. To reconcile the results obtained using the two approaches requires the effects of crack damage to be superimposed upon the laboratory seismic data. To assess the density of macroscopic cracks, outcrop crack lengths were measured in the field and from photographs. Assuming crack length follows a power law relation to frequency, this fixes a small portion of the power spectrum, which is then extrapolated to cover the likely full range of crack sizes. The equations of Budiansky and O'Connell linking crack density to elastic moduli were used to calculate modified acoustic velocities, and the effects of the wide range of crack sizes were incorporated by breaking the distribution down into bins of limited range of crack density. In this way it has proved possible to reconcile the laboratory and field velocity measurements.

The seismic tomography results show particularly well the location of steeply-dipping fault cores and the decoration of fault zones with intrusive igneous material, and these correlate well with the results of geological observations.