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Integrated geoelectrical and seismic mapping of the concealed Carlsberg Fault, Copenhagen, Denmark

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The Carlsberg Fault is located in a NNW-SSE striking fault system in the border zone between the Danish Basin and the Baltic Shield. Recent, small earthquakes indicate that this area is tectonically active. We locate the concealed Carlsberg Fault zone along a c. 20 km long trace in the Copenhagen city center by seismic refraction, reflection and fan profiling. We supplement our seismic investigations with multi-electrode geoelectrical profiling. The seismic refraction study shows that the Carlsberg Fault zone is a low-velocity zone and marks a change in seismic velocity structure. A normal-incidence reflection seismic section shows a coincident flower structure. We have recorded seismic signals in a fan geometry from shots detonated both inside the low-velocity fault zone and up to about 1 km away from the fault zone. The seismic energy was recorded on a total of six receiver arrays (1.5-2.5 km long arcs) across the expected location of the 400-700 m wide fault zone at distances of up to 10 km from the shots. Shots detonated inside the fault zone result in: 1) weak and delayed first arrivals on the receivers located inside the fault zone compared to earlier and stronger first arrivals outside the fault zone; 2) strong guided P- and S-waves as well as surface waves inside the fault zone. The fault zone is a shadow zone to shots detonated outside the fault zone. Finite-difference wavefield modelling supports the interpretations of the fan recordings. Our fan recording approach facilitates cost-efficient mapping of fault zones in densely urbanized areas where seismic normal-incidence and refraction profiling are not feasible. The geoelectrical measurements show that the fault zone is characterized by low resistivities ($<$ 5 ohmm), indicating that the fault zone is fractured and water-filled. This interpretation is supported by hydrological measurements conducted by others, which show that the Carlsberg Fault zone is highly permeable.