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Active tectonics of the Dinarides in Slovenia - new data from remote sensing, field studies, geophysics, and palaeoseismology

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The northward motion of the Adriatic plate with respect to the Alps leads to thrusting on E-W striking fault in NE Italy and to right-lateral strike-slip faulting on NW-SE trending Dinaric structures in W Slovenia. GPS data allow to understand the collision on a regional scale, but the networks are either not dense enough to draw conclusions on the activity of individual faults, or displacement rates across these faults are below GPS resolution. Instrumental seismicity in the Alpine-Dinarides transition zone is higher than elsewhere in the Alps. However, only few reliable moment tensor solutions of moderate to strong earthquakes depict the slip vectors and the geometry of single faults, and the background seismicity >M3 is rather diffuse. Strong historical earthquakes with magnitudes exceeding M6 are documented in our study area, but in most cases they cannot be tied to the fault that ruptured. Published paleoseismic evidence for surface-rupturing earthquakes is very limited, but geomorphological studies have shown that a number of thrust faults in NE Italy and strike-slip faults W Slovenia have been active in the Quaternary.

So far there is little data on slip rates of individual faults, on their earthquake history and recurrence intervals, and on their seismic potential. It is not clear if crustal deformation is distributed across many active structures or if few main faults take up most of the deformation. The transition between head-on thrusting in N Italy and right-lateral motion on NW-trending faults in Slovenia needs further research.

In this study we used remote sensing, field studies, near-surface geophysics, and palaeoseismology to better understand crustal deformation as a response to the Adria-Alpine convergence. We focussed on the right-lateral strike-slip faults in W Slovenia. High-resolution digital elevation models from LiDAR and drones allowed us to image geomorphological evidence of active tectonics and potentially surface-rupturing earthquakes in the Late Quaternary. The widespread karst made it difficult to apply classical techniques of tectonic geomorphology, which mainly use landscape features shaped by surface drainage and the associated sedimentation and erosion. However, the high-resolution data proved to be useful in identifying offset and deformed marker surfaces. Field mapping and structural data helped to trace the active faults and to determine their sense of motion. Near-surface geophysics were applied to image the shallowest parts of several faults and to identify deformation in young geological units. Based on these data we excavated paleoseismological trenches to date paleo-earthquakes.

Our results show that a number of roughly parallel, NW-SE trending strike-slip faults in Slovenia have been active in the Late Quaternary. Crustal deformation appears to be not taken up by one or two main structures only, but rather distributed in a wide shear zone and across many faults. This is in contrast to the Alpine front further west in NE Italy, where deformation is rather localised on S-vergent thrusts along the front of the Southern Alps. Given the low rate of overall deformation, the distributed faulting results in low fault slip-rates and large recurrence intervals of strong and even surface-rupturing earthquakes.